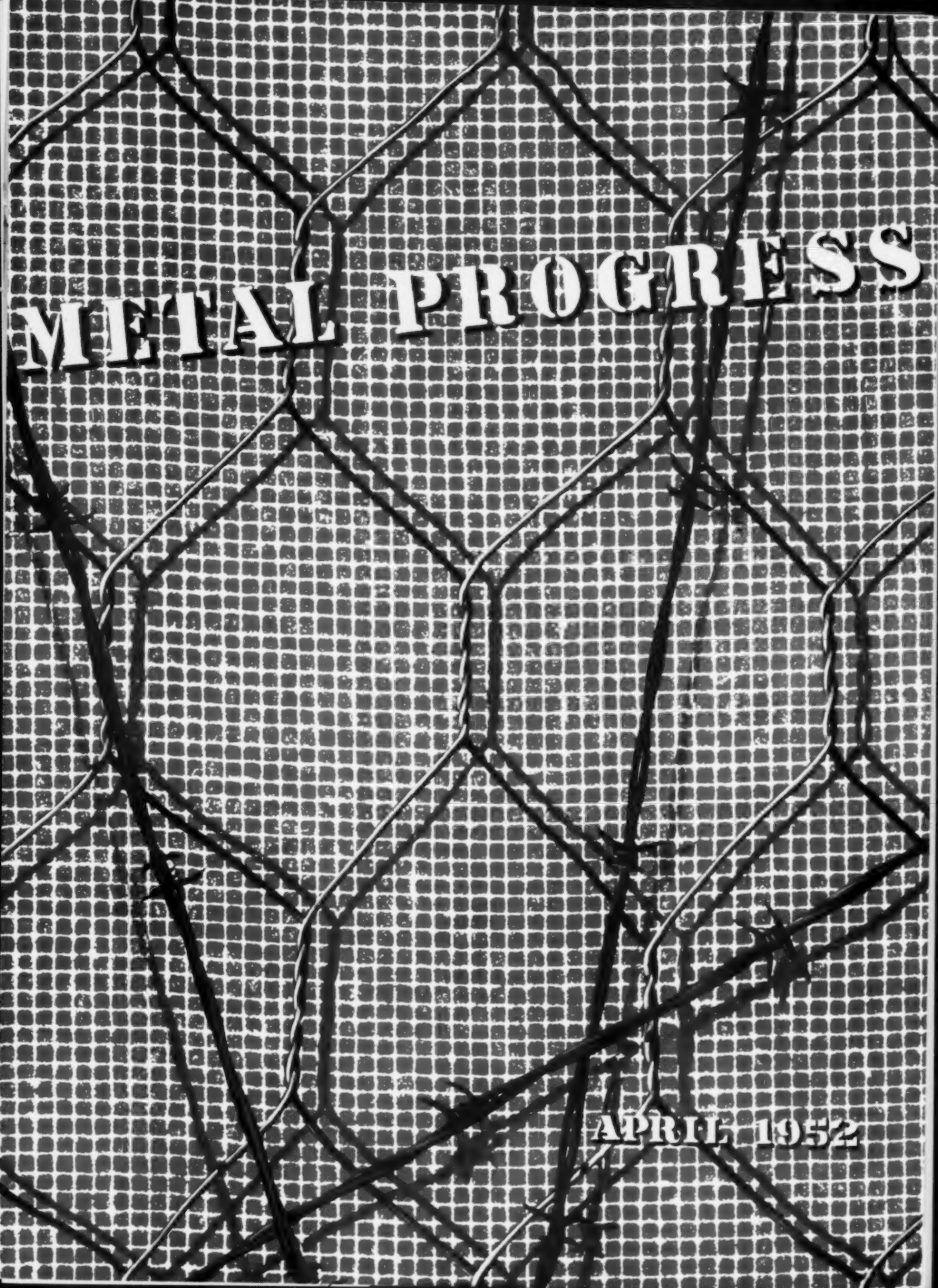
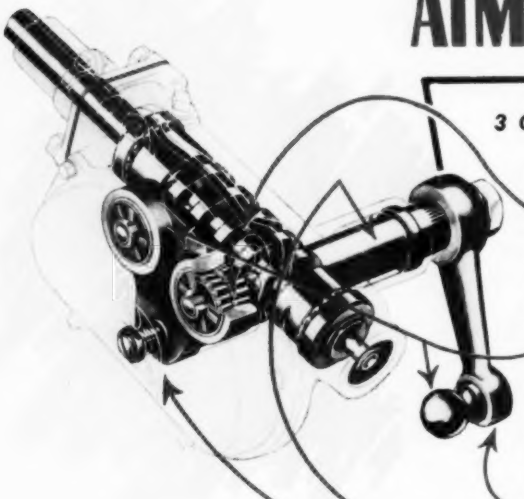

METAL PROGRESS
APRIL 1952

There's Long, Hard Wear in STEERING GEARS

...PUT THERE BY 'SURFACE' RX PREPARED ATMOSPHERES



3 Controlled Atmospheres for Heat Treating

Work flow in the plant producing this steering gear is arranged around 3 controlled atmosphere processes: *carburizing, dry cyaniding, clean hardening.*

- **Carburizing:** Steering gear cams, the "heart" of the assembly, are carburized in 4 'Surface' pit type radiant tube furnaces each with an enriched RX controlled atmosphere. Each furnace handles about 1500 lbs. net. Minimum hardenable case depth of 0.040-in.
- **Dry Cyaniding:** Studs and balls subject to frictional wear and impact stress in final assembly are given optimum physical properties by a dry cyaniding treatment with a 'Surface' RX atmosphere enriched with natural gas and ammonia. Studs are cyanided to case depth of 0.008-in. Balls are treated to case depth of 0.010-0.015-in. Heat treatments are accomplished in a continuous articulated link belt furnace.
- **Clean Hardening:** Lever shafts and steering arms are first isothermally annealed, then clean hardened in a 'Surface' rotary hearth furnace with radiant tubes and an RX controlled protective atmosphere.

Ever hear of an auto accident due to steering gear going bad? Quite likely you never will, because right before your eyes is proof that steering mechanisms (other parts and products, too) are made safe and dependable.

All vital and moving parts of the steering assembly shown above undergo one or more controlled atmosphere heat treatments: *carburizing, cyaniding, clean hardening,* where results are uniform and consistently within close tolerances.

These controlled atmosphere heat treatments are carried out in radiant tube-fired furnaces of types best suited for handling the particular parts. The furnace types include pit, rotary hearth and continuous articulated link belt types.

RX PREPARED ATMOSPHERES

Atmospheres for these 3 distinctly different heat treat processes are prepared in 2 centrally located 'Surface' RX generators manifolding the RX carrier gas for all atmosphere requirements. Saves money, saves space!

'Surface' RX generators for making prepared atmospheres are employed successfully in hundreds of plants for many processes: carburizing, clean hardening, bright annealing, carbon restoration, homogeneous carburizing and dry cyaniding.

'Surface' is a pioneer in prepared atmosphere equipment, furnishing not only RX, but also DX, NX, HX, HNX, AX and Char-Mo gas atmospheres. *Send for Bulletin SC-155 on prepared atmospheres. Write today on your letterhead.*

'Surface'
INDUSTRIAL FURNACES

SURFACE COMBUSTION CORPORATION · TOLEDO 1, OHIO

IN THIS ISSUE

Table of Contents — p. 65

New Products — p. 16

Advertisers' Index — p. 192

As I was saying–

I NEVER grow weary of telling this story, which is ever new to a large number of new members of :

The A.S.M. was organized in 1913 in Detroit by Billy Woodside . . . had then 12 members, now 21,000; 60% are engaged in the fabrication of metals, 25% in production of ferrous and nonferrous metals, 15% in education and research . . . is the only engineering society dealing with all phases of the metals industry . . . is the largest group of metal engineers in the world . . . has 80 chapters holding 500 meetings a year with 50,000 attendance . . . sponsors chapter educational courses attended by over 16,000 annually . . . publishes the Metals Handbook, bible of the metals industry . . . publishes *Metal Progress*, the engineering magazine of the metals industry . . . publishes *Transactions*, the technical volume of annual convention papers . . . supplies over 45,000 preprints of convention papers . . . publishes *Metals Review* containing the only prompt and complete review of metal literature.

In one year the collected, edited, printed and distributed over 100 million pages of engineering information on the subject of metals.

 conducts the most intense promotion in the world for ferrous and nonferrous metals . . . produces and distributes moving pictures on metallurgical subjects . . . provides a no-cost employment service . . . has distributed over 100,000 booklets and leaflets describing a career as a metals engineer . . . is the largest publisher of engineering books for the metals industry in the world . . . owns and operates the National Metal Exposition and the Western Metal Exposition . . . holds an annual metallographic exhibit . . . is the instigator and general manager of the National Metal Congress . . . is *sole* sponsor of the World Metallurgical Congress.

Through the Metallurgical Advisory Board, appoints committees to serve as advisory to the United States Navy . . . also serves by appointment as the agency for the distribution of metallurgical information to the profession.

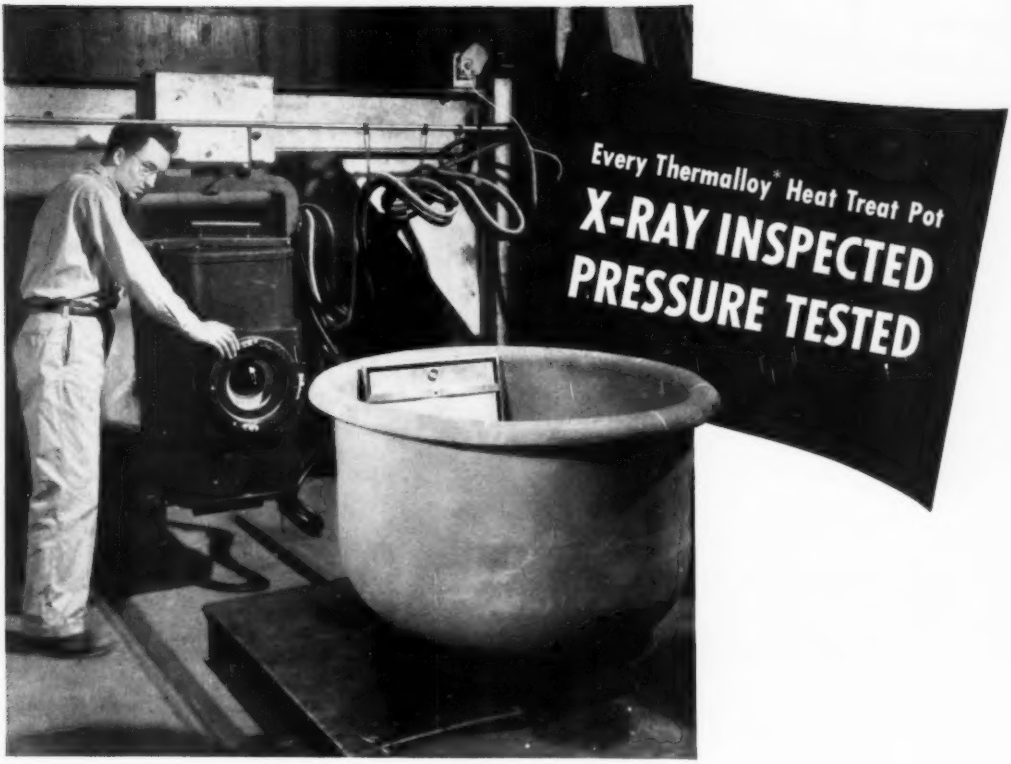
 has not increased its dues ($10) since the Society was organized . . . returns an average of 40% ($85,000 each year) to the chapters . . . expends annually on each member $44.50 . . . has an annual budget of over one million dollars . . . has established the annual teaching awards in metallurgy . . . is fathering the establishment of a new highly technical and theoretical international publication for the metals industry . . . and many other important projects now in the making and soon to be announced.

From where I sit it seems to me that all the members of the should be mighty proud of their fine accomplishments enumerated above, because they never would have been possible without the 100% cooperation of 100% of the members.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS



HERE'S PROOF OF QUALITY!

- Life of Electro-Alloys neutral salt pot proved to be eight times that of competitive type pot formerly used. User saved over $100 on initial cost alone during life of one pot—plus replacement labor costs of seven pot changes.

- With a competitive alloy, customer was receiving 1,500 to 3,500 hours service. On switching to Thermalloy pots, service life jumped to 3,800-5,550 hours in identical service.

Another reason why you get
More Operating Hours per Dollar

To insure the soundness necessary for low-cost service, every Thermalloy Heat Treat Pot is subjected to thorough internal and external inspection. Two X-ray machines, operated by trained radiographers, reveal any hidden flaws or weaknesses which might shorten service life. Pots are also pressure-tested at 60 pounds per square inch. This eliminates the possibility of porosity that does not show up on X-rays.

This careful inspection, plus Thermalloy's outstanding heat-resistant properties, are your guarantee of top quality. Why not make Thermalloy your standard in buying heat treat pots?

Over 100 sizes in both round and rectangular pots are available for production from stock patterns. Write for Bulletin T-205, listing shapes and sizes available. Electro-Alloys Division, 2094 Taylor St., Elyria, Ohio.

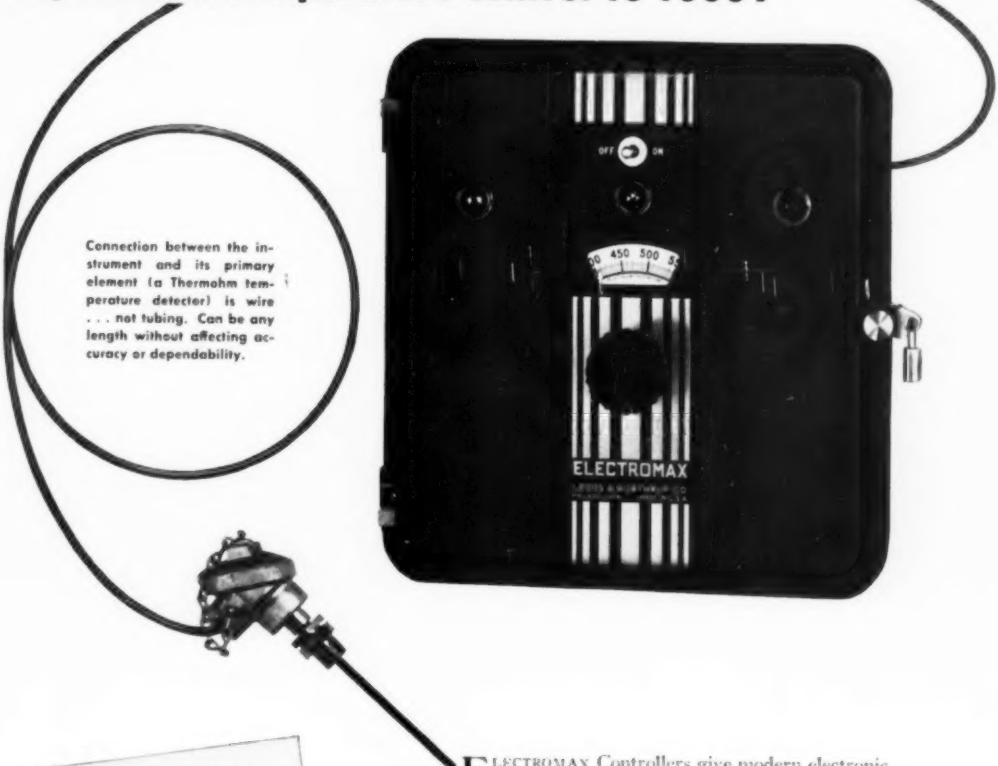
Specify THERMALLOY* for heat and abrasion resistance... CHEMALLOY* for corrosion resistance

*Reg. U. S. Pat. Off.

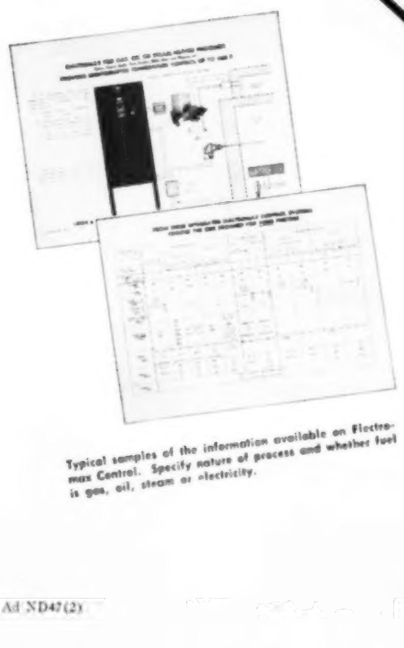
AMERICAN **Brake Shoe** COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

Dependable temperature control to 1000 F



Connection between the instrument and its primary element (a Thermohm temperature detector) is wire . . . not tubing. Can be any length without affecting accuracy or dependability.



Typical samples of the information available on Electromax Control. Specify nature of process and whether fuel is gas, oil, steam or electricity.

ELECTROMAX Controllers give modern electronic regulation to thousands of important manufacturing processes. In any application up to 1000 F they exactly fill the bill for non-recording controllers of outstanding dependability.

Electromax has the sensitivity, accuracy and dependability of its big brother Speedomax Recording Controller. Likewise, it is not affected by vibration or building tremors . . . can even be mounted on the frame of a molding press. The instrument needs almost no attention, because it has only one moving part . . . a covered plug-in type relay. There's usually no need to open the instrument door for months at a time.

Electromax Control is available to provide any one of three control actions. For the more simple process requirements, on-off or two position control is usually used. For processes requiring control within unusually close limits, two different types of proportional control are available . . . Position-Adjusting Type and Duration-Adjusting Type. All three types of control action can be applied to electric, steam or fuel heating.

For further information, write our nearest office, or 4927 Stenton Ave., Phila. 44, Penna.

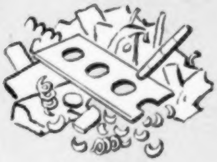
MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl Ad ND47(2)

Metal Progress is published and copyrighted, 1952, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

HOW THE *SCRAP* THAT JACK MADE —MADE JACK *AND MORE*



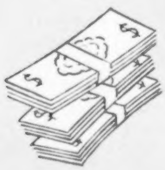
This is the Scrap that Jack made.

This is the Man who found the Scrap that Jack made.

This is the Clerk who was called by the Man who found the Scrap that Jack made.

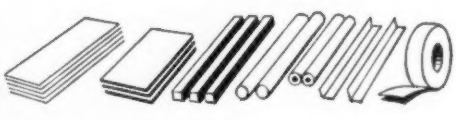
This is the Dealer who dealt with the Clerk who was called by the Man who found the Scrap that Jack made.

AND TO MAKE THE STORY SHORTER:



This is the jack the dealer paid for the Scrap that Jack made.

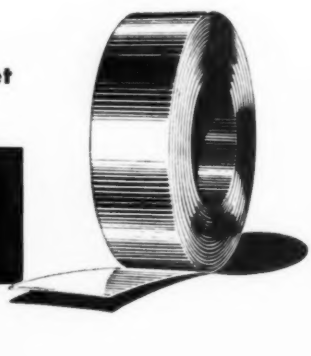
AND THIS IS THE STEEL THAT INDUSTRY GETS



from the Scrap that Jack made!

MORAL:

Check your Plant for Scrap Today and Get it Moving — *That* Pays Everybody!



Superior Steel
CORPORATION
CARNEGIE, PENNSYLVANIA

UTICA HELPS

The name, UTICA, famous for quality forged tools for more than 50 years, now identifies a foremost supplier of turbine and compressor blades to the aircraft engine industry.

BY MAKING TODAY'S METHODS "OLD FASHIONED"

...there is no horizon on new ideas at UTICA

In the forging of turbine and compressor blades UTICA is using the most modern methods, the finest equipment and the skill born of long experience in forging.

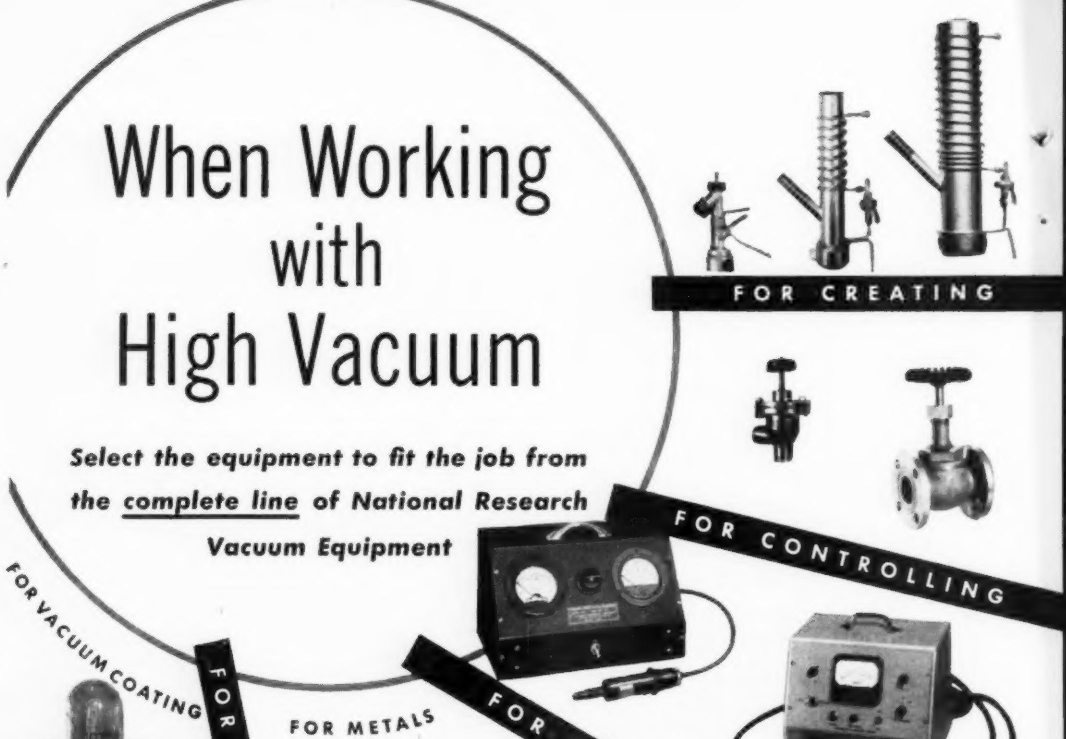
But, the constant search for improvements goes on.

Our engineers and metallurgists work and plan continually to make today's methods obsolete.

So, whether you come into contact with UTICA tomorrow or several years from now, you'll find leadership that reflects this constant hunger for progress. UTICA seeks to help most by working most for advancement.

U TI CA

UTICA DROP FORGE & TOOL CORPORATION, Utica 4, New York


When Working with High Vacuum
Select the equipment to fit the job from the complete line of National Research Vacuum Equipment
FOR CREATING
FOR CONTROLLING
FOR MEASURING HIGH VACUUM
FOR VACUUM COATING
FOR METALS
FOR PROCESSING IN HIGH VACUUM

MAGNESIUM

and the problem of FABRICATION

in your product

Today American industry is constantly searching for ways to lighten the unprecedented load on its production facilities. Progressive manufacturers have discovered that magnesium . . . with its combination of lightness, strength and workability . . . is one answer. These characteristics of magnesium can result in simplified design, speedier fabrication and lowered production costs.

Manufacturers find that magnesium is produced in all common forms including castings, forgings, extrusions and sheet. They learn that it can be machined at the highest possible speeds of standard machine tools . . . can be formed by drawing, spinning, bending, stretching and other common production methods. Also that the metal is joined by arc, gas, and spot welding as well as by riveting and is finished by accepted methods.

So if you are making, or contemplate making, anything in which lightness or ease of fabrication is important, plan with magnesium. It has made many products better—more versatile, easier to handle, more profitable to sell—it may improve yours.

For Your "Tomorrow's" Product . . .

Today, magnesium is a tremendously important part of our defense effort, and like many other metals, is required in great quantities by the government. But in planning "Tomorrow's" production, remember this fact: the seas, at our own shores can provide 100 million tons of magnesium per year for 1,000,000 years without significantly reducing the supply!

THE DOW CHEMICAL COMPANY
Magnesium Department • Midland, Michigan

New York • Boston • Philadelphia • Atlanta • Cleveland • Detroit • Chicago • St. Louis • Houston
San Francisco • Los Angeles • Seattle • Dow Chemical of Canada, Limited, Toronto, Canada

Here's how to

HOLD THAT LINING

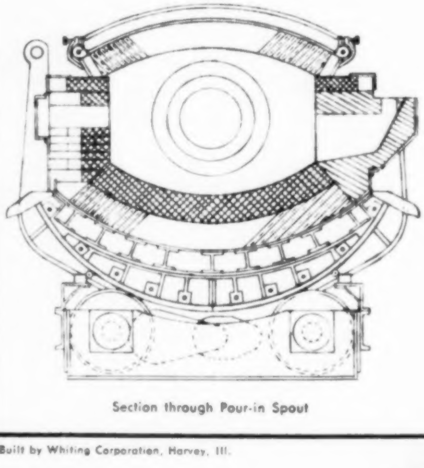
in your holding furnace

Operators of Whiting* Cradle and similar types of holding furnaces use Taylor Sillimanite (TASIL) brick and cement to prolong the life of refractory linings. Recommended practice is to "*balance*" the super-duty fire brick lining with 9" of TASIL brick, laid in TASIL No. 301 Cement, for both side walls and bottom, in the areas subject to the damaging wash of molten iron and slag. (See refractory construction shown in engineering drawings below.)

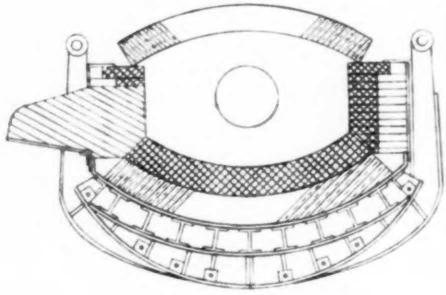
A TASIL "balanced" lining at one plant is averaging 6-8 weeks on side walls and 9-12 months on bottoms, with patching. TASIL was tried after a super-duty fire brick lining failed in three days because of joint attack and severe erosion at the metal line. This furnace is fired with pulverized coal and runs 700 tons per week of grey iron, tapped from cupola at 2750° to 2800° F.

Wherever you use fireclay-base, high alumina, kaolin or similar refractories, TASIL will give more effective service. Let a Taylor field engineer discuss with you the savings Taylor Sillimanite can make in your plant.

Tasil "Balanced" Lining In Whiting Cradle Furnace



Section through Pour-in Spout



Section through Pour-out Spout

TASIL sidewalls and bottom 9" thick. TASIL top course in sidewall 13½" thick.

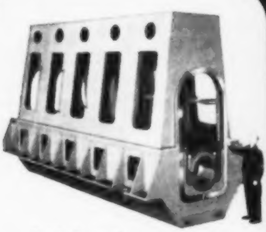
= Taylor Sillimanite

* Built by Whiting Corporation, Harvey, Ill.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

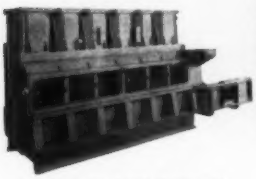
The CHAS. TAYLOR SONS Co.
A SUBSIDIARY OF NATIONAL LEAD COMPANY
REFRACTORIES SINCE 1864 • CINCINNATI • OHIO • U.S.A.

Steel-Weld FABRICATION

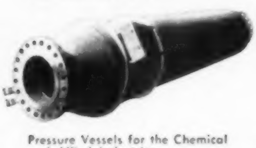


Crank Cases, Frames, and other Parts for Manufacturers of Marine Steam Engines of Uniflow or Multiple Expansion Type.

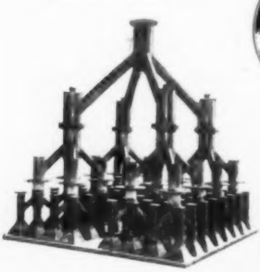
Heavy Press and Machine Frames and Bases for the Machine Tool Industry.



Diesel Engine Crank Cases and Frames for the Marine and Electro-Motive Field.



Pressure Vessels for the Chemical and Allied Industries.



One of Several Parts of a Catalytic Cracking Plant Produced for the Petroleum Industry.

Use WELDED STEEL for Greater Strength with Less Weight!

Mass production of these massive clutch and drive housings for a twenty-one ton tractor is further evidence of the design trend in modern machines . . . it is a typical example of how alert manufacturers are today employing Steel-Weld Fabrication to good advantage in the construction of their products. Thousands of such heavy machinery parts and assemblies are now produced and machined by Mahon for many manufacturers throughout the country. If savings in either cost or time can be effected in your product through Steel-Weld Fabrication of parts, or, if you are cramped for manufacturing space, it will pay you to investigate Mahon facilities. You will find in the Mahon organization an unique source with complete, modern fabricating, machining and handling facilities for any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job embodying every advantage of Steel-Weld Fabrication.

THE R. C. MAHON COMPANY
DETROIT 34, MICHIGAN

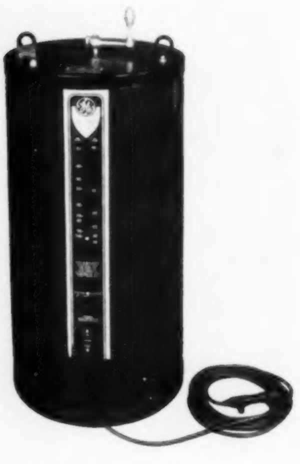
Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

Engineering Digest

OF NEW PRODUCTS

WELDER: A redesign of its atomic-hydrogen transformer welder, incorporating a new hot-start circuit, silicone insulation and a wider current range, has been announced by the General Electric Co. The current range of 10 to 100 amp. allows the use of one



machine on all applications. The range is divided into two sections, each extending the entire length of the indicator scale. The welder operates on 60 cycles, single-phase voltage; it is 41½ in. high and weighs 350 lb.

For further information circle No. 674 on literature request card on p. 32B

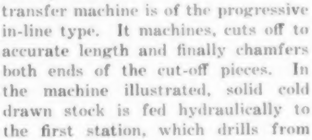
CUTTING FLUIDS: Magnus Chemical Co. has announced the addition of specialty cutting fluids to their line of industrial cleaning materials and machines. These fluids are designed for difficult machining operations, such as work on stainless steel, high-carbon steels and other metals where general-purpose cutting fluids cause excessive tool wear and poor surface finishes. The Magnus products contain a much higher sulphur base content; when used for such jobs they have displayed a cost advantage over general-purpose fluids and those to which white lead or carbon tetrachloride have been added. Magnus cutting compound No. 7, undiluted, is recommended for unusually difficult machining operations. For moderately difficult jobs, 1 part No. 7 may be added to 2-5 parts of general-purpose fluids. Where staining of copper is to be avoided, Magnus cutting compound No. 6 is recommended. For difficult machining jobs where greater cooling qualities are required, Magnus soluble oils DO-4A and DO-1A are recommended. These, with their high concentration of sulphur base, are also formulated to give good rust protection and minimize the occurrence of rancidity and dermatitis. Either product is diluted 1-5 to 1-20 for machining operations, depending on the severity of the jobs, and 1-35 to 1-45 for grinding.

For further information circle No. 675 on literature request card on p. 32B

CARBURIZING BOX: The Stanwood Corp. has incorporated V-type skids for a carburizing box, giving better support for heavy loads under high-temperature use. The new construction has also resulted in improved air circulation under the bottom of the box. One-piece combination cast bottoms and legs are available for extra-heavy loading.

For further information circle No. 676 on literature request card on p. 32B

TRANSFER MACHINE: Motch & Merryweather's newest automatic transfer machine is of the progressive in-line type. It machines, cuts off to accurate length and finally chamfers both ends of the cut-off pieces. In the machine illustrated, solid cold drawn stock is fed hydraulically to the first station, which drills from



both sides. The second operation is a countersink of the drilled hole. The third and fourth stations broach flats on both sides of the stock. The fifth station cuts off where a circular saw head rapid traverse approaches, cuts to accurate length a section of the machined stock held by transfer unit, and rapid traverse returns. The hydraulic transfer unit, holding the machined and cut-off piece, returns to position on the side where two drilling units feed to adjustable stops, chamfer both ends of the piece simultaneously, and rapid traverse returns.

For further information circle No. 677 on literature request card on p. 32B

EXTENSOMETER: A complete line of newly designed high-magnification S-type extensometers is now available from Tinius Olsen Testing Machine Co. These light weight instruments, which detect strain under both elastic and plastic tension test, transmit signals which rotate the recorder drum in direct proportion to strain on the specimen. Snapped on or off the specimen by merely squeezing the clamp plates, each instrument

is provided with three high magnifications. As the specimen stretches, an activating knife edge moves, which in turn moves the core of a differential transformer. This movement creates an a-c. voltage which is amplified to operate a two-phase recorder motor which drives the recorder drum on which the strain is recorded. Standard S-type extensometers are available for gage lengths of 1, 1.4, 2 and 8 in. with magnifications up to and including 1000.

For further information circle No. 678 on literature request card on p. 32B

FINISHES FOR ALUMINUM: New hard coatings for aluminum where high resistance to abrasion is desired are being released to licensees by Aluminum Co. of America. These coatings have special value where hard, long-wearing surfaces coupled with light weight are essential, as in surfaces subjected to abrasion or erosion. The new wear-resistant finishes are anodic oxide coatings. Some are made by the well-known Alumilite

See next page for list of THINSTEEL products

The Cold Metal Products Company invites your investigation of the cost-saving possibilities in your processing operations by testing CMP Cold Rolled Strip Steel products in any of these regularly produced grades:

(1) Low Carbon Cold Rolled Strip Steel—Coils or Cut Lengths—

(a) #2 finish (standard cold rolled finish); or #3 best bright finish (a mirror-like finish for plating)

(b) Electro-zinc-coated — a phosphate base with zinc coating for corrosion resistance purposes and suitable for enameling or painting

(c) Annealed, intermediate, or hard rolled tempers

(d) Non-scalloping quality, to eliminate or reduce trimming operations

(e) Thicknesses .001" and heavier

(2) Cold Rolled High Carbon Spring Steel—Coils or Cut Lengths—

(a) Any practical controlled structure for best response to required heat treatment

(b) Annealed or rolled tempers

(c) #2 regular cold rolled finish or #3 mirror finish

(d) Thicknesses .001" and heavier

(3) Cold Rolled Stainless Strip Steel—

(a) #2 finish (standard cold rolled finish); or #3 finish (an extra bright mirror-like finish produced by rolling)

(b) Bright annealed tempers in chrome-nickel grades as well as in straight-chromium grades

(c) High tensile grades from 125,000# PSI minimum up to 200,000# PSI minimum or more where desirable

(d) High hardness values in 400 series obtained by special heat treatment

(e) Thicknesses .001" and heavier

(4) Cold Rolled Alloy Strip Steel—

(a) Standard alloys

(b) #2 regular cold rolled or #3 mirror finish

(c) Specifications can be varied to meet unusual requirements in cooperation with our Laboratory controlled processes

(5) Tempered Spring Steel—

(a) Scaleless blue

(b) Tempered and polished

(c) Tempered, polished and colored

(d) CMP Tempered Specialities Steel for Feeler Gauges, Vibrator Reeds, Camera Main Springs, Band Saws, Tapes, and Clicker Steel

CMP THINSTEEL products may be ordered direct from the mill, or for less than mill quantities or for emergency service needs, from the following warehouses:

Kenilworth Steel Company, 750 Boulevard, Kenilworth, New Jersey, 'phone N. Y. COrtlandt 7-2427 or N. J. Unionville 2-6900

Precision Steel Warehouse, Inc., 4409-4425 West Kinzie Street, Chicago 24, Illinois, 'phone COlumbus 1-2700

The Cold Metal Products Company of California, 6600 McKinley Avenue, Los Angeles, California, 'phone PLeasant 3-1291

the Cold Metal Products co.

YOUNGSTOWN 1, OHIO

New York • Chicago • Indianapolis • Detroit • St. Louis • Los Angeles • Cleveland

process. Alcoa has also acquired the U. S. patent rights to the Martin hard coating for aluminum from the Glenn L. Martin Co. The MHC finish is similar to the Alumilite coatings in hardness and structure. The Glenn L. Martin Co. reports that the MHC finish has been used successfully in the solution of problems of wear, abrasion, heat erosion, and corrosion in such diversified articles as gears and pinions, turbine impeller blades, nozzles, the leading edges of high-speed airfoils, and leg braces for paraplegics. MHC-finished aluminum has been applied to many parts of Martin aircraft, such as pistons, cylinders, jack-screws, walkways, door mechanisms, and other applications in which the finish has permitted aluminum-for-steel substitutions which have cut weight and operating costs.

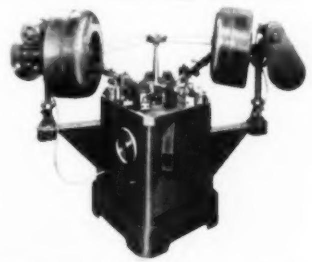
For further information circle No. 679 on literature request card on p. 32B

PRECISION CASTING FURNACE: Developed especially for high-speed production of precision castings, this new mechanically-operated Ajax-Northrup induction furnace transfers molten metal from furnace to mold in any pre-set cycle, usually only a few seconds. Typical of high-performance parts being cast with the

new units are jet engine vanes and blades, compressor parts and small ordnance components. Operation is extremely simple. At the end of the melting period — 12 min. for 5 lb. of alloy steel — the preheated mold or investment is clamped directly to the top of the crucible with a specially-fitted holder. Operation of a control lever causes the furnace to rotate to pouring position. The new furnace, made by Ajax Electrothermic Corp., is powered by a standard Ajax-Northrup 20-kw. mercury-hydrogen type of converter, and operates at a frequency of about 30,000 cycles. The converter can also be used to power other melting furnaces, or for various types of heating equipment, as for heat treating or brazing.

For further information circle No. 680 on literature request card on p. 32B

THREAD ROLLING MACHINE: First to incorporate the efficient "planetary" principle, the Prutton "Rollmaster" introduces unique engineering features for high-speed thread rolling in a wide variety of metals ranging from nonferrous to hardened and stainless steels. The machine produces threads of class 3 fit at



18,000 to 20,000 pieces per hr., including set-up time. The Rollmaster threads bolts, fetter ring and spiral nails, and does many knurling, marking, serrating, necking and contour operations.

For further information circle No. 681 on literature request card on p. 32B

INSTRUMENT PEN: New industrial instrument pens have been designed by Minneapolis-Honeywell Regulator Co. for their strip-chart electronic instruments. The new pens have removable tips and a new reservoir construction which eliminates flooding. Other advantages are: The

pen operates with decreased pressure on the instrument chart, tending to reduce paper fiber choking; thorough cleaning is made easy by a simple disassembly, and the new design fits on standard pen carriages, permitting improved performance for already installed instruments.

For further information circle No. 682 on literature request card on p. 32B

SUBZERO MACHINE: A new model industrial chilling machine to meet the needs of smaller capacity users has been announced by Deepfreeze Distributing Corp. The new model, W-120, has a capacity of 5 cu.ft., and will maintain temperatures as low as minus 120° F. At this temperature it will remove 500 Btu. per hr., the equivalent of cooling 20 lb. of steel from room temperature to minus 120° F. The W-120 is expected to be of special interest to operators of smaller heat treating departments. The increased use of subzero temperatures for quick and complete stabilization has developed a need for such units in heat treating plants and departments whose size did not necessitate the larger capacity models.

For further information circle No. 683 on literature request card on p. 32B

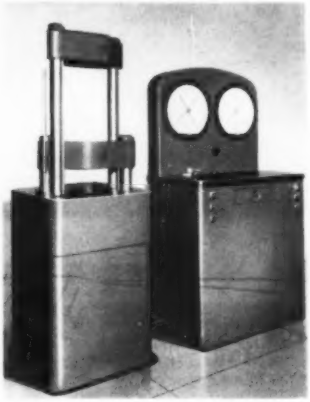
LIQUID HONING: A new liquid honing machine by Vapor Blast Mfg. Co. has been developed for use in honing tools, broaches, hobs, taps and drills and larger tools like dies and molds. It can be operated from either sitting or standing position.

For further information circle No. 684 on literature request card on p. 32B

BRAZING FLUX FOR TITANIUM: Handy & Harman announces the development of a brazing flux for use in the joining of titanium and zir-

conium and their alloys. Silver brazing alloys readily wet the titanium which is protected by the flux. Although titanium and zirconium form brittle compounds with most metals and alloys that may be used for brazing, the embrittlement may be minimized by rapid heating and limiting the time at brazing temperature. For this reason, low-temperature brazing alloys are preferred. The new flux is called Special Handy Flux for Titanium.
For further information circle No. 685 on literature request card on p. 32B

TESTING MACHINE: An improved, low-cost universal testing machine of 120,000-lb. capacity is announced by Baldwin-Lima-Hamilton Corp. The hydraulic loading unit is separate

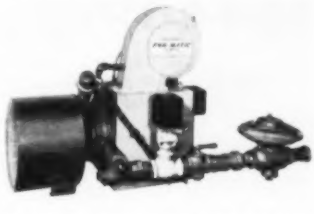


from the indicating and control unit, which isolates recoil from breaking test specimens and permits adjusting maximum or lazy hands with minimum drag. Load (either in tension or compression) is applied upward by an integrated piston and elevating cage. Loading speed can be varied infinitely between 0 and 2 in. per min. Two ranges, 0 to 120,000 and 0 to 30,000 lb., are standard. Any two of six other ranges are available, and three ranges can be provided.
For further information circle No. 686 on literature request card on p. 32B

ALKALINE DERUSTING: Announcement of the development of a new alkaline derusting process for steel, cast iron, malleable iron and other ferrous alloys is made by Enthone, Inc. Because the process is alkaline, it simultaneously cleans and derusts. In one test, complete rust and scale removal was accomplished in 2 min. as against 45 min. for acid pickling. This is important where high-speed pickling of wire or strip must be accomplished. The process is applicable for derusting without a heat source being available.

The operation of the bath is simple. Parts heavily contaminated with grease should first be degreased. However, light oil is readily removed in the bath. The parts are then immersed in the derusting solution where they are made the cathode for periods varying from a few seconds to several minutes, depending on current density and condition of the surface. A wide range of current density can be employed from five to several hundred amperes per square foot. After derusting, the object is clean and bright. Longer treatment does not result in any attack upon the metal being pickled. Therefore, close watching of the pickling process is not required. One of the chief advantages claimed for the process is due to the fact that it is alkaline and there is no tendency to cause surrounding equipment to be corroded, such as occurs with acid pickling processes.
For further information circle No. 687 on literature request card on p. 32B

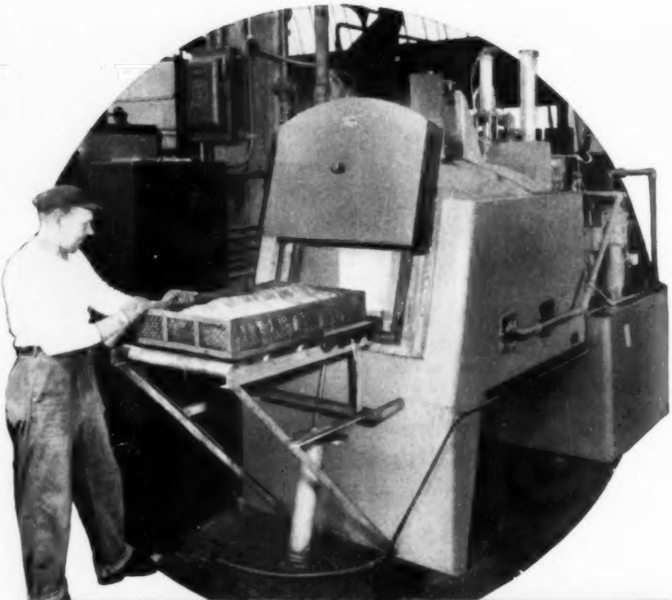
COMBINATION GAS-OIL BURNER: Eclipse Fuel Engineering Co. announces the new Fyr-Matic gas-oil burner, designed for industrial and commercial use in applications where both oil and gas are available. Changeover from one fuel to the other is made instantly and automatically by the flick of a switch. This new combination burner makes it possible to alternate the use of fuels back and forth according to availability, economy or suitability. Mixed, natural or L-P gas (800 to 3200 Btu.) or No. 1, 2, or 3 fuel oil may be used in the burner, all operating with equal efficiency. Either gas or oil can be burned without induced secondary air, as the burner is designed to



furnish its own air for complete combustion. Positive ignition is assured with either fuel; with oil, direct electric spark ignition is employed; for burning gas, ignition is provided by a gas pilot which must "prove" itself to the electronic safety circuit before the main fuel is admitted to the burner.
For further information circle No. 689 on literature request card on p. 32B

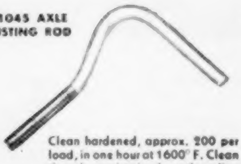
DIE-CASTING MACHINES: The Lake Erie Engineering Corp. has introduced an improved line of die-casting machines, incorporating two exclusive features, the "wedge cam toggle" and the "pressure-pac" injection unit. The former is a self-compensating toggle clamp which automatically takes up clearances in the dies due to contraction and expansion of the molds during production or shut-down periods. The new injection unit facilitates production of denser castings by providing the necessary pressure to feed the shrink or to compress the porosity at the time of solidification of the metal. The new line of machines is available in 10 models, ranging from 100 to 1000-ton capacity, for casting all the usual nonferrous metals and alloys.
For further information circle No. 688 on literature request card on p. 32B

DISTORTION
REDUCED... PRODUCT QUALITY IMPROVED
with a...



Ipsen T-250 Heat Treating Unit in large Farm Equipment plant. Operator simply loads the unit and sets the heat treating cycle. Work is handled through heat and quench (or cooling) cycle automatically. Change-over from one job to another is fast and simple.

SAE-1045 AXLE ADJUSTING ROD



Clean hardened, approx. 200 per load, in one hour at 1600° F. Clean threads maintained, rethreading operation eliminated. Wt. per piece — .37 lbs.

SAE-1095 TRIGGER SPRING

Clean hardened, 350 per load, in 30 minutes at 1500° F. Distortion reduced, cleaning operation eliminated. Wt. per piece — .19 lbs.

SAE-1045 HITCH HOOK

Clean hardened, 60 per load, in one hour at 1600° F. A scale-free and a more rust resistant finish is produced, cleaning operation eliminated. Wt. per piece — 4 lbs.

SOFT-CENTER STEEL JOINTER BLADE

Clean hardened, 69 per load, in one hour at 1625° F. Distortion reduced, cleaning and buffing eliminated. Wt. per piece — 3.1 lbs.

NEW IPSEN STANDARD
AUTOMATIC HEAT TREATING UNIT

Described at left are typical results obtained by a Farm Machinery Manufacturer in clean hardening more than 50 different workpieces on a production basis in an Ipsen Automatic Heat Treating Unit. Controlled, automatic batch processing from heat through quench, combined with sealed atmosphere operations, have also effected important improvements in product quality. For example, highly uniform results are now obtained from load to load which permits more accurate control of wear. Also clean, scale-free, more rust-resistant work is obtained. Further, distortion is held to close limits, which not only speeds production but also simplifies assembly and field service problems.

Bright Carbonitriding Cuts Processing Time 75%

In addition, 15 different workpieces requiring case depths ranging from .015 - .035" are also automatically processed in the Ipsen. On these jobs, the Ipsen exclusive bright carbonitriding process is employed. This method cuts processing time as much as 75%, and improves delivery schedules. Workpiece distortion is also accurately controlled, and extra handling and cleaning operations are eliminated. In use for more than nine months, the unit has operated on a 24 hour schedule, with no downtime for maintenance.

Write **FOR MORE FACTS TODAY** — Get the complete story on modern Ipsen Heat Treating Units today. Three standard sizes are available — from 250 to 600 lb. capacities. Write for free data sheets describing and illustrating results and procedures on actual jobs.

THE AUTOMATIC Ipsen HEAT TREATING UNIT

IPSEN INDUSTRIES, INC., 723 South Main Street, Rockford, Illinois

Production units for CARBONITRIDING · CARBURIZING · HARDENING · BRAZING · MARTEMPERING

What's New

IN MANUFACTURERS' LITERATURE

690. Abrasive Belt Machines
30-page illustrated booklet of case histories. *The Porter-Cable Machine Co.*

691. Air-Gas Mixer
Engineering and application data on series "LP" air-gas proportional mixer is available in Bulletin L-300. *Eclipse Fuel Engineering Co.*

692. Alloy Selection
New 24-page booklet, "Long-Wearing Machinery Parts", shows sizes and shapes of parts made of Haynes alloys. *Haynes Stellite Co.*

693. Alloy Steel
New 16-page, pocket-size booklet entitled "Republic Alloy Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

694. Alloy Steel
Booklet on Carilloy steel tells how No. 4150 and others provide toughness, strength and lightweight durability under trying conditions of service. *U. S. Steel Co.*

695. Alloys
28-page bulletin describes alloys available including ferro-alloys containing titanium and boron, pure metallic titanium and zirconium, and zirconite. *Titanium Alloys Mfg. Co.*

696. Alloys, Fabricated
Catalog available showing cost-cutting fabricated heat treating equipment for higher payloads and better quality. *Rolock, Inc.*

697. Aluminum Forgings
New book covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Section on metallurgy gives commercial alloy compositions, physical properties and tolerances. *Aluminum Co. of America.*

698. Annealing
Booklet on burner especially designed for annealing furnaces and other uses where flame impingement is not permissible. *Bloom Engineering Co., Inc.*

699. Anti-Carburizing Paint
Descriptive literature is available on paint which prevents carburizing or hardening of certain spots on steel parts. *Case Hardening Service Co.*

700. Arc Welders
Illustrated booklets available on both A-C and D-C arc welders. Contain data and diagrams on construction and uses. *Westinghouse Electric Corp.*

701. Austempering
Article on modified austempering of cylinder liners at Jacobs Aircraft Co., from current issue of "Tips and Trends". *Ajax Electric Co.*

702. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way Corp.*

703. Barrel Finishing
Bulletin describes new chemical in paste form for descaling, roughing, deburring, cleaning, and finishing nonferrous parts by barrel tumbling. *Blue Magic Chemical Specialties Co.*

704. Belts
Illustrated catalog 47P describes metal material-handling belts. *Ashworth Bros.*

705. Bimetal Elements
64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

706. Blast Cleaning
16-page booklet analyzes basic problems involved in blast cleaning and peening operations. Measures effectiveness of metal abrasives. *Hickman, Williams & Co.*

707. Brazing
Bulletin 20 tells of advantages of Easy-Flo silver brazing alloy. 24-page bulletin gives information about joint design and fast production methods. *Handy & Harman.*

708. Brazing

50-page text GEA-3193 describes the methods and applications of electric-furnace brazing. *General Electric Co.*

709. Brazing Alloys

New 8-page illustrated booklet explains uses of phos-copper and phos-silver extruded alloys for torch brazing, furnace brazing and resistance brazing of copper, brass and bronze. Also data on brazing flux for ferrous and nonferrous metals. *Westinghouse Electric Corp.*

710. Brazing, Silver

48-page, pocket-size manual on all aspects of silver brazing applications and problems. *The American Platinum Works.*

711. Brazing Washers

Free sample of silver brazing alloy pre-formed washer coined from wire. *Lucas-Milhaupt Engineering Co.*

712. Bronze

Vol. 8, No. 1, of the Lavingot technical journal contains discussions of effects of various elements in manganese bronze. *R. Lavin & Sons, Inc.*

713. Burners

Burner Catalog B-11 lists full line of standard burners from ribbon flame burner to simple, efficient soldering iron. Dimension tables, schematic drawings, output charts. *C. M. Kemp Mfg. Co.*

714. Camera Microscope

Complete information on construction, operation and special features of MEF universal metallurgical camera microscope. *Wm. J. Hacker & Co., Inc.*

715. Carbon Control

Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup Co.*

716. Carbon and Sulphur Analysis

Folder, punched for insertion in standard three-ring binder, describes induction furnaces for carbon and sulphur analysis. *Laboratory Equipment Corp.*

717. Case Hardening Compound

Technical data on Aerocase, case hardening compound. *American Cyanamid Co.*

718. Castings, Centrifugal

12-page illustrated bulletin on centrifugal castings of steel in permanent metal molds. *Lebanon Steel Foundry.*

719. Chromium Stainless Steels

Folder gives applications of various chromium stainless steels. Includes table of analyses and properties. *Lebanon Steel Foundry.*

720. Cleaning

Bulletin 214 gives full details, specifications and actual performance on faster blast cleaning with Rotoblast barrels. *Pangborn Corp.*

721. Cleaning

Information on new cleaning process that uses emulsion cleaners, based on petroleum and addition agent 240. This two-phase bath provides unique cleaning in conjunction with a thin displacement film that removes foreign particles. *Northwest Chemical Co.*

722. Cleaning

New booklet entitled "Your Metal Rearmament Products" contains outline of most efficient methods of handling, as well as cleaning, metal products for defense. *Alvey-Ferguson Co.*

723. Cleaning and Buffing

"Barrel Finishing of Metal Parts" contains interesting data on barrel deburring, as well as methods of removing many kinds of burrs from sawing, drilling, milling and stamping operations. *Magnus Chemical Co.*

724. Cleaning and Finishing

Attractive 12-page, well-illustrated catalog A-652 gives the complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines operating in large metalworking plants. *R. C. Mahon Co.*

725. Cleaning Equipment and Materials

Series of attractively illustrated bulletins informs concerning dry cleaning process, degreasers, metal parts washers, degreasing solvents, emulsion and alkaline cleaners and rust proofing compounds. *Detrex Corp.*

726. Cobalt Alloy

12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite Co.*

727. Combustion Control

Booklet No. A-801 describes Heat Prover, an instrument which measures combustion efficiency of any type furnace using any form of fuel. *Cities Service Oil Co.*

728. Continuous Casting

12-page catalog describes properties, sizes and weights of continuous cast bronzes. *American Smelting & Refining Co.*

729. Continuous Sampling

4-page descriptive and illustrative bulletin on continuous sampling monitor—a new device to simplify quality control. Explains operation, construction, range. *General Electric Co.*

730. Coolant

Eight case histories on use of company's coolant concentrate in grinding, tapping, threading, turning, drilling and forming. *Master Chemical Corp.*

731. Copper Alloy Forgings

12-page booklet provides practical, comparative illustrations on die-pressed copper alloy forgings. Contains tabulation of physical properties of copper and copper alloys suitable for forgings. *The American Brass Co.*

732. Copper Alloy Tubes

An extensively illustrated 32-page brochure deals with causes of corrosion and means of combating them as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

733. Copper Tubing

6-page illustrated folder gives useful data on seamless copper tubing. Chart featuring safe working internal pressures for both annealed copper and hard copper seamless tubing. *Penn Brass & Copper Co.*

734. Corrosion-Inhibiting Metal Waxes

Data sheet of physical characteristics and application methods for solvent-type and emulsion-type metal waxes for protective finishes. *S. C. Johnson & Son, Inc.*

735. Corrosion Resistance

Single-page technical discussion of factors affecting corrosion resistance of stainless steels. *Cooper Alloy Foundry Co.*

736. Cutting Oil

32-page bulletin of case histories on use of all-purpose base in various machining operations. *E. F. Houghton & Co.*

737. Cutting Oils

New bulletin on "Gulf Electro Cutting Oil" which contains larger percentage of active sulphur ingredient, recommended for toughest machining jobs. *Gulf Oil Corp.*

738. Cutting Oils

Factual data on more than fifty typical metalworking jobs are presented in new 80-page edition of "Cutting and Grinding Facts". Also describes straight and emulsifiable cutting oils with convenient chart for correct use. *Sun Oil Co.*

739. Cutting Oils

Shop notebook giving important facts on right cutting fluid for any machining operation. *D. A. Stuart Oil Co.*

740. Cut-Wire Shot

Economies and characteristics of cleaning and peening with cut-wire shot are described in a 4-page folder. *Cleveland Metal Abrasive Co.*

741. Demineralizer

Folder on water demineralizer for laboratories and electroplaters. *Eberbach Corp.*

742. Descaling Process

Illustrated folder gives advantages and various features of sodium hydride positive descaling. *E. I. duPont de Nemours & Co.*

743. Die-Casting Machines

Illustrated booklet giving specifications, application data and full explanations of two new production advantages on company's line of die-casting machines. *Lake Erie Engineering Corp.*

744. Die-Casting Machines

Illustrated catalog shows complete line of die casting machines. *Kux Machine Co.*

745. Die Steel

New literature available on Bethlehem Cold-Headed Die Steel for high production in forging bolts, rivets, screws, and other products at high speed. *Bethlehem Steel Co.*


PARTS FOR GIANTS...
A REGULAR JOB
FOR MIDVALE CRAFTSMEN
When the job is big . . . the specifications exacting . . . and the quality to be unsurpassed . . . let Midvale do it.
Press cylinders are one example of Midvale's "extra" in service and quality. For years we have made press cylinders for our own huge presses . . . gained untold experience so we could make our customers' products better . . . built this "first-hand know-how" into the finest, most dependable cylinders industry can produce.
Midvale's modern plants are equipped to make, shape, heat-treat and machine parts for giants in all industries. Pressure vessels for the petroleum and chemical industries . . . rolls for the paper industry . . . roll shells and rings for the mining and cement industries . . . weldless rings for turbines and gears . . . castings and forgings for all industries. If the job is big and must be exact, let Midvale engineers and craftsmen help you.
Press cylinder produced by Midvale for 11,000 ton capacity press for large steel plant in southwest.
DIMENSIONS:
Length outside: 7 ft., $10\frac{3}{4}$ in.
Length inside: 6 ft., $11\frac{3}{4}$ in.
Outside Diameter: 66 in. ($\pm\frac{1}{32}$ in.)
Inside Diameter: $51\frac{1}{2}$ in. ($\pm\frac{1}{32}$ in.)
THE MIDVALE COMPANY
NICETOWN, PHILADELPHIA, PENNA.
OFFICES: NEW YORK • CHICAGO • PITTSBURGH
WASHINGTON • CLEVELAND • SAN FRANCISCO
MIDVALE
Custom Steel Makers to Industry
PRODUCERS OF FORGINGS, ROLLS, RINGS, CORROSION AND HEAT RESISTING CASTINGS

746. Electric Furnaces
Bulletin No. 473 describes rocking, automatic melting machine for various ferrous and nonferrous alloys. *Detroit Electric Furnace Div.*

747. Electron Microscope
The new table model RCA electron microscope is described and illustrated in a 12-page booklet. *Radio Corp. of America.*

748. Electropolisher
A bulletin on the theory and practice of electrolytic polishing of metallurgical samples includes description of Buehler-Waisman electropolisher. *Buehler, Ltd.*

749. Extruded Aluminum
40-page illustrated brochure on use of extruded aluminum for moldings and other applications. *Youngstown Manufacturing, Inc.*

750. Fabricating Stainless
48-page illustrated booklet furnishes data on many types of fabrication. Includes machining, pickling and welding. *Republic Steel Corp.*

751. Fabrication
Illustrated folder describes facilities for mass production of defense prime contract and subcontract work. *Charles T. Brandt, Inc.*

752. Finishes
New 4-page, two-color bulletin describes in detail the entire line of Iridite finishes for nonferrous metals. Also includes section ARP process chemicals such as bright hardeners for zinc and cadmium plating and other specialties. *Allied Research Products, Inc.*

753. Flow Meters
Catalog C-12 gives complete line of meters and accessories for measuring pressure, vacuum and differential pressure of liquids and gases. *Meriam Instrument Co.*

754. Forging Steel
Bulletin 31 furnishes helpful information on stainless forging problems and includes specific data on chemical composition of alloy steels. *Timken Roller Bearing Co.*

755. Forgings
Catalog G1 illustrating types of upset and hammer forgings manufactured for various applications. *The Commercial Shearing & Stamping Co.*

756. Forming
Special bulletin of metal spinning, stamping and fabricating facilities. *C. A. Dahlin Co.*

757. Furnaces
Bulletin 435 describes new furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell Co.*

758. Furnaces
Production electric heat treating furnaces are described in Bulletin 1051. Types include those for continuous brazing and sintering, bright annealing, forging and general heat treating. *Harper Electric Furnace Corp.*

759. Furnaces
Catalog W-2 for descriptive matter on tool hardening equipment Model VP (vertical type) and Model 2V. *Sentry Co.*

760. Furnaces
Folders describe chain belt conveyor furnace, radiant tube gas heated, oil or electrically heated. Also other production furnaces. *The Electric Furnace Co.*

761. Furnaces
Heavy-duty box furnaces that provide uniform temperatures for hardening production tools are described in bulletins HD-341 and HD-441. *Hevi Duty Electric Co.*

762. Furnaces
Eight sizes in gas or electric models as well as conveyorized and batch or pot-type furnaces in bulletin 84P. *Despatch Oven Co.*

763. Furnaces
New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

764. Furnaces
Literature describing the use of Marshall tubular furnaces for constant and uniform temperature, furnished in types suitable to your needs. Also radial brackets in stationary and compensating types. *Marshall Products Co.*

765. Furnaces
16-page booklet "Proven Heat-Treating Efficiency" containing attractive four-color illustrations displays complete line of furnaces. *Loftus Engineering Corp.*

766. Furnaces
Complete "Buzzer" catalog available describing Buzzer high-speed gas furnaces designed primarily for heat treating high carbon and alloy steels and also atmospheric pot hardening furnaces for salt, cyanide and lead hardening. *Charles A. Hones, Inc.*

767. Furnaces
38-page illustrated bulletin, "Harnessing Heat", deals with uses of 14 types of gas and electric furnaces. Section on controlled atmospheres. *Westinghouse Electric Corp.*

768. Furnaces, Annealing
Illustrated booklet on continuous vertical strip annealing furnaces, both single and multiple strand. *The Drever Co.*

769. Furnaces, Continuous Annealing
Folder of performance and cost data on radiant tube and roller hearth furnaces for heat treating. *The Gas Machinery Co.*

770. Furnaces, Melting
Catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and eliminate skew shapes. *American Bridge Co.*

771. Gages
Bulletin BG-MP describes highly accurate beta radiation gage used for thickness measurements. One model measures thickness of material accessible from one side only. *Tracerlab, Inc.*

772. Galvanizing
Reprint "Modern Hot-Dip Galvanizing" deals with dross formation as a cause of zinc waste. Detailed information on zinc ammonium chloride type of flux. *Hanson-Van Winkle-Munning Co.*

773. Gas Analyzer
Instrumentation data sheet 10.15-3a describes indicating and recording flue gas analyzer which gives continuous record of combustion analysis. *Minneapolis-Honeywell Regulator Co.*

DETREX
PHOSPHATE COATINGS

Cold Form Steel with amazing new ease!

EXTRUDITE PROCESS

interlocks lubricant with work surface!

The Extrudite Process opens the door to faster, less-wasteful cold forming of steel and other metals. This Detrex development chemically interlocks a dry, heat-resistant lubricant to the work surface . . . metal-to-metal friction is prevented even during the most severe working conditions.

Savings are tremendous on operations such as wire and tube drawing, deep drawing, cold heading and room temperature extrusions. To name but a few of the benefits; operations are speeded up on present equipment, tooling lasts longer, parts are produced with less scrap and many process anneals and chemical treatments are eliminated.

The Extrudite Process consists of a special phosphate coating which becomes integral with the work surface. Then a compatible lubricant is applied which drys to a tough, crystalline lubricating film. Thus the treated metal is clean and easy to handle.

If you are now performing or considering cold forming operations, the Extrudite Process should be investigated. **Detrex Corporation, Box 501, Detroit 32, Michigan.**

X-1

Details of the Extrudite Process and its advantages are contained in this informative bulletin. Send for yours today, there is no obligation.

DETREX CORPORATION

ALKALIES AND EMULSIONS • WASHERS • DEGREASERS
METAL COLD FORMING PROCESSES • DEGREASING SOLVENTS
RUST PROOFING PROCESSES • DRYCLEANING EQUIPMENT

774. Gas Carburizer
Bulletin 1212 illustrates and describes No. 4 rotary gas carburizer for use with small parts. *American Gas Furnace Co.*

775. Gear Hardening
Folder on application of induction heating to high-production hardening of gears. *Westinghouse Electric Corp.*

776. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

777. Grinding Titanium
Article on grinding wheels and techniques for titanium, from "Grits and Grinds". *Norton Co.*

778. Hand Pyrometer
Data sheet GEC-846 on hand pyrometer with scale ranges of 0 to 500 and 0 to 1500° F. *General Electric Co.*

779. Hardfacing
New wall chart which details the proper hardfacing rod for the job. *American Manganese Steel Div.*

780. Hardfacing Rods
Five bulletins cover company's complete line of hard facing alloy rods. *Victor Equipment Co.*

781. Hardness Tester
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, outlining experiences in various fields. *Wilson Mechanical Instrument Co.*

782. Heat Exchangers
Bulletin No. 35-76C and illustrated folder No. 250 discuss equipment for use in quenching operation and other uses. *American District Steam Co.*

783. Heating Elements
Bulletin H gives detailed information on AT-type nonmetallic electric heating elements, including tables for a wide variety of sizes, available. *Globar Div., Carborundum Co.*

784. Heating of Plating Baths
Illustrated bulletin on unit heat exchangers designed to maintain working temperature of nickel plating solutions by continued heating or cooling in the same unit. *Industrial Filter & Pump Mfg. Co.*

785. Heat Treating
Catalog 116 contains 72 pages of factual heat-treating data for carburizing, cyanide hardening, brazing, austempering, and annealing processes. *Ajax Electric Co.*

786. Heat Treating
Handy vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam Industrial Furnace Div.*

787. Heat Treating
Bulletin 120 tells how Niagara Aero Heat Exchangers provide better heat control in quenching bath, thus protecting physical properties and saving on water and piping equipment. *Niagara Blower Co.*

788. Heat Treating
Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. *Ipsen Industries, Inc.*

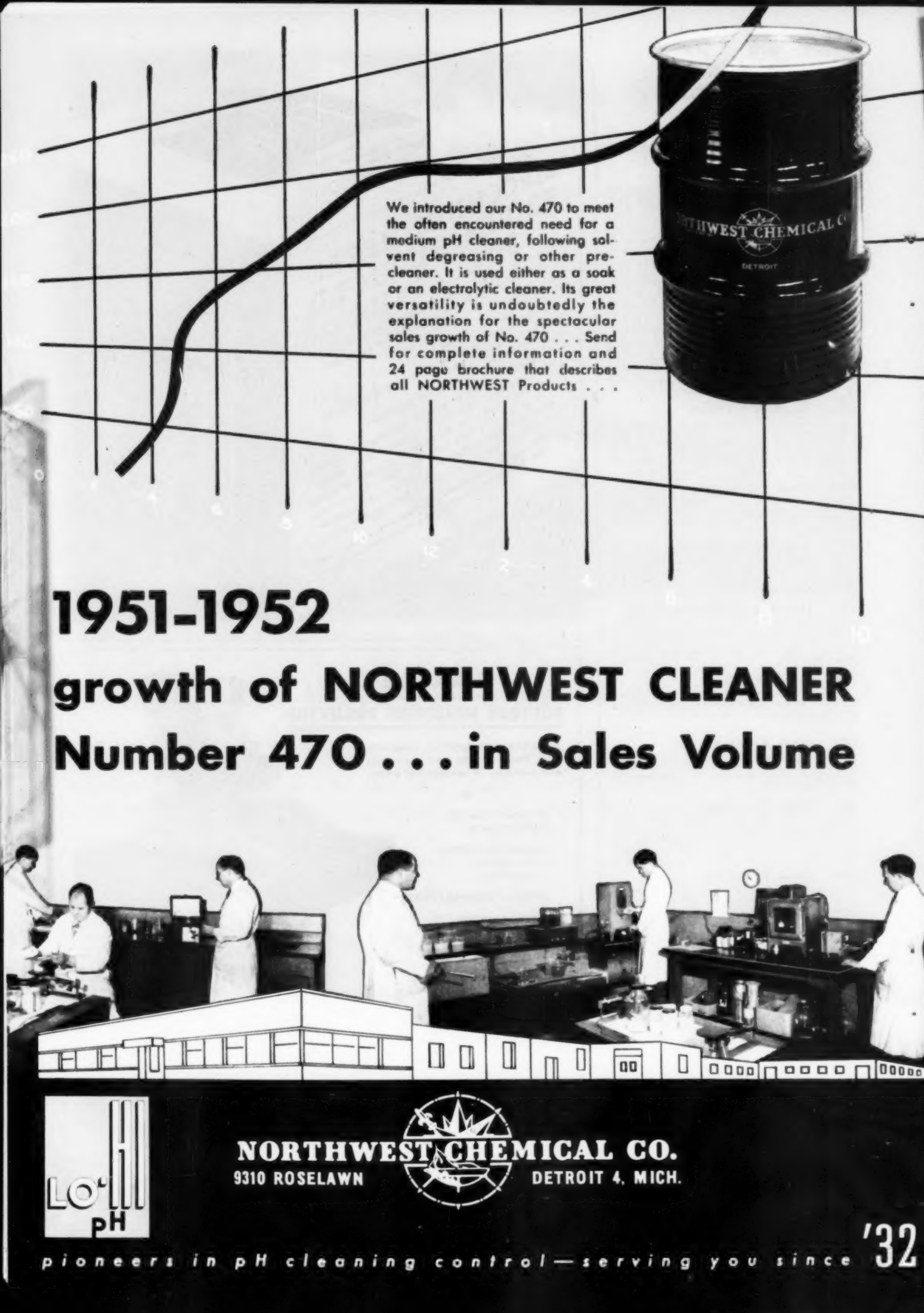
789. Heat Treating
40-page booklet on facilities for tool heat treat, bright hardening of stainless, case hardening, machine quenching, cleaning, straightening and inspection. *Commercial Steel Treating Corp.*

790. Heat Treating
24-page "Story of Malcomizing" describes surface hardening of stainless steels. Includes case histories. *Lindberg Steel Treating Co.*

791. Heat Treating
Booklet describes complete diversified facilities for steel, aluminum and magnesium heat treating. *Pearson Industrial Steel Treating Co.*

792. Heat Treating Atmospheres
Bulletin SC-155 on prepared atmospheres for all heat treating requirements. *Surface Combustion Corp.*

793. Heat Treating Baskets
Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described in catalog 16. *Stanwood Corp.*


We introduced our No. 470 to meet the often encountered need for a medium pH cleaner, following solvent degreasing or other precleaner. It is used either as a soak or an electrolytic cleaner. Its great versatility is undoubtedly the explanation for the spectacular sales growth of No. 470 . . . Send for complete information and 24 page brochure that describes all NORTHWEST Products . . .
NORTHWEST CHEMICAL CO
DETROIT
1951-1952
growth of NORTHWEST CLEANER
Number 470 . . . in Sales Volume
LO' HI pH
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DETROIT 4, MICH.
pioneers in pH cleaning control—serving you since '32

794. Heat Treating Fixtures
Information on complete line of standard carburizing carriers that will handle odd-shaped parts of every type thru carburizing and quenching to finishing. *Pressed Steel Co.*

795. Heat Treating Pots
New bulletin T-205 lists 118 patterns available in Thermalloy heat treating pots, both round and rectangular, X-rayed and pressure tested for sound and economical service. *Electro-Alloys Div.*

796. High Temperature Alloys
"Inco High Temperature Work Sheet" provides valuable information and suggestions for solving high temperature problems in design and production. *International Nickel Co.*

797. Hydraulic Presses
Bulletin 147, "Practical Facts About Hydraulic Presses", an informative guide for the user of all types and sizes of hydraulic presses. *Lake Erie Engineering Corp.*

798. Identifying Metals and Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *The International Nickel Co., Inc.*

799. Identifying Stainless Steel
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel Co.*

800. Induction Heating
Catalog MP-4 describes portable high frequency induction heating unit for brazing, hardening, soldering, annealing and melting. *Lepel High Frequency Labs., Inc.*

801. Induction Heating
"Induction Heating . . . the machine tool that makes tall stories come true" presents case histories of how induction heating has increased production, reduced space and cut costs. *Westinghouse Electric Corp.*

802. Induction Heating
Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

803. Induction Melting
Bulletin describes the application of induction heat to melting of metals. *Ohio Crankshaft Co.*

804. Industrial Planning
New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

805. Instruments
"Tomorrow Is Today" is a new brochure telling of the many contributions of instruments to industrial processing. *Minneapolis-Honeywell Regulator Co.*

806. Instruments
New, 28-page catalog No. 5000 describes the principal instruments, control devices and related components manufactured by the company. *Minneapolis-Honeywell Regulator Co.*

807. Instruments
Capacitrols and capacilines are described in bulletins PC-1 and CL-1. *Wheelco Instruments Co.*

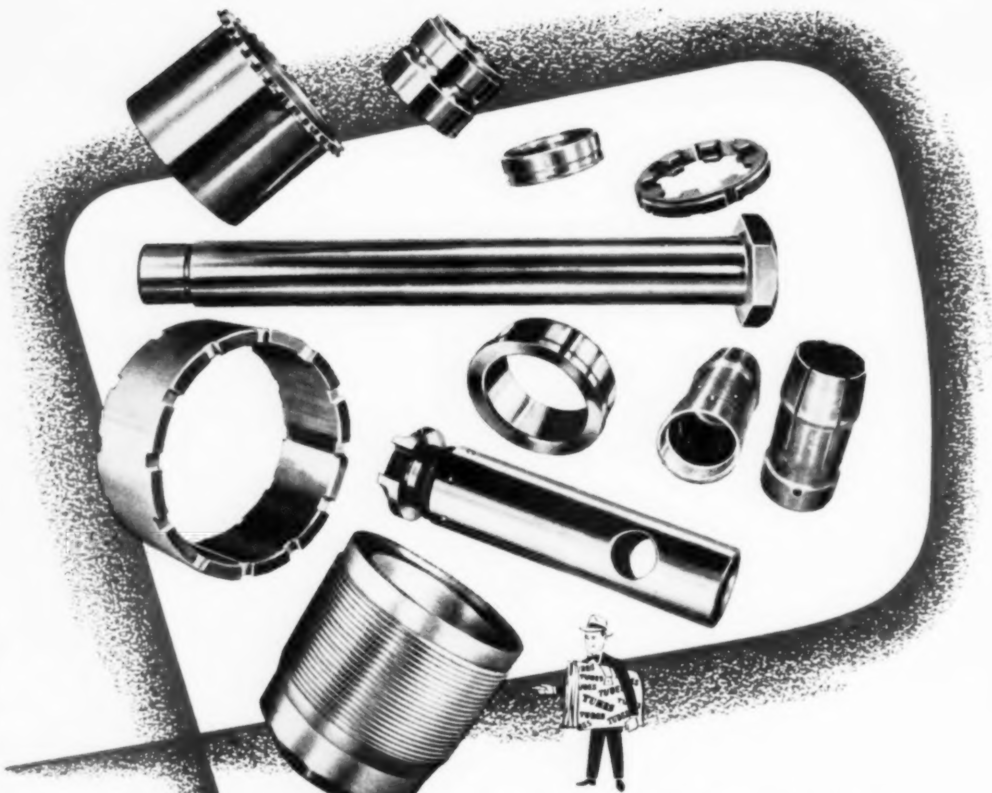
808. Iron, Ductile
New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. *International Nickel Co.*

809. Laboratory Furnaces
Series of data sheets give full information on complete line of laboratory furnaces for numerous metallurgical operations. *Boder Scientific Co.*

810. Lubrication, Metalworking
The uses of colloidal graphite for hot metalworking operations (deep piercing, casting, forging, stretch-forming and wire drawing operations) are explained in bulletin No. 426-10D. *Acheson Colloids Corp.*

811. Magnesium
42-page booklet on processing and properties of wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping Corp.*

812. Magnesium Die Castings
Book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co.*



Since machining is probably the most widely used method of producing hollow parts from steel tubing, keeping well-informed calls for periodic review of the characteristics of tube machining operations and new developments in this field. A new slant on types of tubing, grades of steel, mechanical properties and dimensional tolerances could show you the way to reduce overall time and costs.

Let's take a closer look at your MACHINING REQUIREMENTS

Because B&W's long experience has *proved* the value of never-ending investigation to find *new uses for tubing's adaptability*, B&W keeps reminding people who work with metal that tubing is more than bar stock with a hole in it; it is a semi-finished product. If there's a machining question on your mind these days, why not drop us a line? Tell us end-use of the mechanical tubing, OD, ID, and length of finished part, method of chucking and sequence of machining operations—description of finished product, dimensional accuracy and type of surface finish required. Send along a print if you like.

The B&W Technical Staff will supply objective recommendations and, if you desire, your regional B&W Tube Representative—Mr. Tubes—will step in to help interpret your needs to the home office. Bulletin TB-324 gives an idea of what can be done with fine tubing. Write for it.

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General Offices & Plants

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Alliance, Ohio—Welded Carbon Steel Tubing

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B&W SEAMLESS and WELDED TUBES

TA-1680M

(*Continued from p. 31*)

813. Marform Deep Drawing
Catalog No. L-79-641 describes pressure control mechanism for use in the Marform deep drawing process. *Loewy Construction Co.*

814. Metal Cutting
New 64-page catalog No. 28 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric Co.*

815. Metal Finishing
New check list available on sixty products and processes for metal finishing, including a new acid addition agent, a cleaning and pickling agent combined, a new complete inhibitor and a new rust-preventive compound. *Enthone, Inc.*

816. Metallograph
Revision of catalog will include the new metallograph with polarizing and phase attachments. Now in preparation for early release. *American Optical Co.*

817. Metallographic Polishers
Bulletin 90 shows various models of metallographic specimen polishers. *Eberbach Corp.*

818. Metal Spraying
Article "Metallizing — What It Is, What It Does", in current issue of "The Metallizer". *Metallizing Co. of America.*

819. Metalworking Lubricant
Data sheet on solid waxes in stick form for use as lubricant in sawing, threading, drilling, tapping, spinning and grinding. *S. C. Johnson & Son, Inc.*

820. Micrographic Equipment
6-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000×. Full details on optics and accessories included. *Opplem Co.*

821. Microscopes
Well-illustrated 22-page booklet on Dynoptic Labroscopes, featuring ball bearings and rollers throughout the focusing system as well as low position fine adjustment with low controls that enable the operator to manipulate other controls more easily. *Bausch & Lomb Optical Co.*

822. Modulus Determination
Data sheet on equipment for determination of modulus of elasticity by sonic method that measures resonance frequency of masses weighing up to 1500 lb. *Electro Products Laboratories, Inc.*

823. Moly-Sulfide Lubricant
50-page booklet listing 154 applications for Moly-sulfide lubricant with specific information on each. *Climax Molybdenum Co.*

824. Nickel Alloys
Booklet, "Hastelloy Nickel-Base Alloys", gives full details of their use for fabricating corrosion-resistant screen, cloth and baskets and for metal spraying and hard facing. *Haynes Stellite Co.*

825. Nondestructive Inspection
Data available on electronic inspection equipment, demagnetizers and comparators for sorting. *Magnetic Analysis Corp.*

826. Photography
Catalog, "Kodak Sensitized Materials for the Scientific and Industrial Laboratory", tells of special films, plates and pellicles, transmission curves of filters and filter combinations commonly used in photography. *Eastman Kodak Co.*

827. Piercing
A calculator of the slide-rule type for determining the required pressure (in tons) for piercing a given size hole in any thickness and type of metal. *Ward Machinery Co.*

828. Piping and Tubing
New 68-page book is a practical treatise on pipe and tube making, answering many pertinent questions on tube mill operations and production. *Yoder Co.*

829. Plating Barrels
4-page folder illustrates and describes equipment designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply Co.*

830. Plating Rectifier
Booklet 127 describes d-c. power requirements for electroplating, electropolishing and electrocleaning. Equipment recommendations; descriptions, drawings and photographs of company's line of selenium rectifiers. *Bart-Messing Corp.*

831. Potentiometer, Portable
Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

832. Pots
Bulletin N-1 tells of pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Fuel Engineering Co.*

833. Power Brushes
New 76-page catalog No. 210 simplifies selection of power brush for the individual job; contains numerous colored illustrations of various types of brushes in operation. *Osborn Mfg. Co.*

834. Precision Casting
12-page, illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields included. *Alexander Saunders & Co.*

835. Precision Castings
Illustrated folder, "Cost Reduction Through Investment Casting", shows diversity of parts to which process applies. *Casting Engineers, Inc.*

836. Presses
Press owner's manual contains complete operating and maintenance instruction for latest design straight-side double-crank presses. *E. W. Bliss Co.*

837. Product Information
Entirely new "Product Information File" informs, comprehensively, on time-tested industrial germicides and fungicides. Tells how to bring effective, economical microbial control to plants. *The Dow Chemical Co.*

838. Protective Chemicals
Quick reference list of rust proofing, paint-bonding and metal protective chemicals is intended for all fabricators of steel, zinc and aluminum products. *American Chemical Paint Co.*

839. Protective Coating
Bulletin 600 on phenolic coating resin for protecting steel against corrosion. *Carboline Co.*

840. Pyrometer
Catalog No. 180 gives details about surface pyrometer which gives surface and subsurface temperature readings. *Pyrometer Instrument Co.*

841. Pyrometers
Bulletin GEC-713 and Bulletin GEC-714 describe line of pyrometers and thermocouples. *General Electric Co.*

842. Pyrometer Wires
Chart of color codes, calibration symbols, thermo elements of thermocouple and extension wires for ISA, U.S. Military and Aeronautical specifications. *Thermo Electric Co., Inc.*

843. Quenching Oil
New technical bulletin F-8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

844. Quenching Oil
Booklet, "Sun Quenching Oils", tells of advantages of this line of oils for use in the quenching process. *Sun Oil Co.*

845. Radiography
Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. *Westinghouse Electric Corp.*

846. Radiography
18-page booklet describing company's line of industrial X-ray units in range of power up to one million volts. *General Electric X-Ray Corp.*

847. Recording Meters
New 28-page bulletin E-1111 describ[e]
500 recording voltmeters and ammete[rs]
special emphasis on newly-developed mov[ing]
measuring mechanism. Complete data o[n]
and specifications of various models for pe[rmanent]
and portable use. *Bristol Co.*

848. Refractories
Revised bulletin entitled "Lumnite R[e]
Concrete" discusses latest available inf[ormation]
on refractories and heat-resistant concret[e]
nite Div., Universal Atlas Cement Co.

849. Refractories
Form 1409 describes the new Nort[on]
stabilized zirconia, ideal refractory for
linings, metal melting, thermal insulatio[n]
for firing titanates and electric heater e[...]
Norton Co.

850. Refractories
20-page booklet gives technical inform[ation]
a basic nature on super refractories. [...]
text, charts, tables, illustrations and ap[...]
data. *Carborundum Co., Refractories Div.*

851. Refractories
New 12-page illustrated brochure prese[nts]
ucts for casting special refractory sha[pes]
products for gunning and slap troweling
tions, for services through 3000° F.
Manville.

852. Refractory Mixes
Well-illustrated 16-page bulletin No. [...]
vides important data on properties and
tions of Sillimanite super-refractory [...]
mixes and patches. *Chas. Taylor Sons Co.*

853. Resistance Thermom[eters]
36-page catalog and buyers' guide f[or]
line of resistance thermometers. Include[s]
tabular guide to selection. *Leeds & Nor[thrup]*

854. Resistance Welding
6-page brochure "Spot and Seam W[elding in]
Aircraft Construction" features Northrop
applications. *Sciaky Bros., Inc.*

855. Rhodium Plating
Directions for rhodium plating, with p[...]
reference to its use as replacement for [...]
plating metals. *Baker & Co., Inc.*

856. Rust Preventive
Technical information available on zi[nc]
phate-type rust preventive conforming t[o]
specifications. *American Chemical Paint*

857. Salt Spray Test Cabi[nets]
Illustrated bulletin describing test cab[inets]
forming to Spec. QQ-M-151a for corrosio[n]
in salt-fog or humidity-laden atmosphere
trial Filter & Pump Mfg. Co.

858. Saws
Catalog 49 describes complete line [...]
cutting saws, covering 35 models in [...]
types, including fast, automatic product[...]
hydraulic hack-saws and widely used s[...]
saws. *Armstrong-Blum Mfg. Co.*

859. Silica Cement
Illustrated folder on use of silica c[ement]
laying silica brick in various types of [...]
Harbison-Walker Refractories Co.

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860. Silicone-Base Finish

New brochure on silicone-base heat-resistant finish is now ready. *Midland Industrial Finishes Co.*

861. Soldering Aluminum

Article on latest techniques and materials developed for soldering aluminum, from "Reynolds Technical Advisor". *Reynolds Metals Co.*

862. Soldering Equipment

8-page brochure on soldering and brazing equipment describes new Mogul soldering gun and shows its applications to production-line soldering and brazing. *Metallizing Co. of America.*

863. Spectrographic Analysis

Article on quantitative spectrographic analysis of zinc die-casting alloys, from current issue of Spectrographer's News Letter. *Applied Research Laboratories.*

864. Spectrophotometer

Bulletin B-211 illustrates junior-size spectrophotometer for identifying and measuring solution constituents in analytical or production laboratories. *Harshaw Scientific Div.*

865. Spring Steel

Handbook describes various spring steels and gives tolerance tables, heat treatment and physical property tables and fabrication data. *A. R. Purdy Co., Inc.*

866. Spring Wire

Detailed information on Pittsburgh oil tempered spring wire to help solve coiling, knotting, forming and twisting operation problems. *Pittsburgh Steel Co.*

867. Stainless Castings

28-page full-color industrial fantasy, "Alloys in Cooperland", captures the spirit of Lewis Carroll in describing how stainless steel castings are made. *The Cooper Alloy Foundry Co.*

868. Stainless Steel

Weekly lists with analyses of all plates in stock and latest data. *G. O. Carlson, Inc.*

869. Stampings

Illustrated brochure on variety of stampings made by company. *The Commercial Shearing & Stamping Co.*

870. Stampings

26-page booklet contains reprint of paper on "How Modern Stamping Techniques Can Help Conversion". *Leake Stamping Co.*

871. Steel, Aircraft

New printing "Aircraft Steels" booklet which includes revised military specs to August, 1951. Also sizes and analyses of aircraft steels carried in stock. *Joseph T. Ryerson & Son, Inc.*

872. Steel Bars

New wall chart of 275 different grades of standard, special and alloy steel bars shows chemical analyses and other data. *LaSalle Steel Co.*

873. Steel, Low-Alloy

Booklet on Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. *Inland Steel Co.*

874. Steel, Low-Alloy

Well-illustrated 8-page folder on N-A-X low-alloy steels lists physical properties and test specifications. *Great Lakes Steel Corp.*

875. Straightening Presses

Folder on hydraulic straightening presses with capacities up to 25 tons. *Anderson Bros. Mfg. Co.*

876. Stud Welding

12-page manual prepared to aid designers and production engineers in the fast, economical solution of fastening problems. Specifications, selection guide included. *Nelson Stud Welding Div.*

877. Temperature Controller

Data sheet on compact input controller and indicating potentiometer, which can be set to regulate current input anywhere from 5 to 100% time on. *Thermo Electric Manufacturing Co.*

878. Temperature Controls

New catalog G-17 describes temperature control instruments. *Burling Instruments, Inc.*

879. Temperature Regulator

Folder giving complete specifications of electrically operated two-position, on-off temperature regulators. *Barber-Colman Co.*

880. Testing

Bulletin on mechanical and nondestructive testing and on certification in accordance with procedure set up by the American Standards Association. *American Standards Testing Bureau, Inc.*

881. Testing Machines

Eight-page folder illustrates current Amsler machines for tests in tension, compression, torsion, shear, fatigue, bending and ductility. Separate bulletins on wear testing and testing of miniature samples. *Buehler, Inc.*

882. Thermocouples and Pyrometer Accessories

56-page book comprising a User's Manual, illustrated Buyers' Guide with specifications and prices and thermocouple calibration data. *The Bristol Co.*

883. Thermometers

New catalog 6020 describes compact approach to time-temperature control of operations such as annealing. Describes new instrument that combines as many as six functions from a standard sized instrument case. *Minneapolis-Honeywell Regulator Co.*

884. Thickness Gage

A 12-page illustrated brochure describes two new model absorption and backscatter beta gages for the determination of weight per unit area of sheet materials. *Tracerlab, Inc.*

885. Tools, Stellite

Tool manual and catalog describes four different grades of cast cutting tool alloys. Gives physical, mechanical and chemical properties of alloys to help in selecting right tool alloy for various cutting operations. *Haynes Stellite Co.*

886. Tool Steel

Circle "M", Star-Mo and Van Chip are three high speed steels described in folders covering mechanical and heat treating data and applications. *Firth Sterling Steel & Carbide Corp.*

887. Tool Steel

86-page pocket-size handbook on application and heat treatment of 27 grades of tool and die steels. *Ziv Steel & Wire Co.*

888. Tool Steel

Information on Warplis products, stock size and price folders will be sent on request, along with name of nearest distributor. *Pittsburgh Tool Steel Wire Co.*

889. Tool Steel

Stock list of available tool and die steels. *Reliable Steel Co.*

890. Tool Steel

Service bulletins, issued regularly, give information on tool steel selection, treatment and use. *Carpenter Steel Co.*

891. Tool Steel Selector

Handy, clearly printed, easy-to-use tool steel selector will be furnished on request. *Crucible Steel Co. of America.*

892. Tube Fabrication

Concise case histories, production stories and equipment descriptions on tube fabrication from "Pine Engineering News". *Pines Engineering Co., Inc.*

893. Tubing

42-page "Handbook on Cold Drawn Butt Welded Mechanical Steel Tubing" discusses processing, utility and types. Illustrated. Many useful tables. *Pittsburgh Tube Co.*

894. Tubing

For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of seamless and weldrawn tubing, send for bulletin 32. *Superior Tube Co.*

895. Tubing

New illustrated catalog shows typical application of electrical weld steel mechanical tubing. Useful engineering charts. *Brainard Steel Co.*

896. Tubing Chart

A chart covering the range of sizes of electric resistance welded tubing produced by company. *Babcock & Wilcox Tube Co.*

897. Turbo-Compressors

Bulletin No. 107-C gives a variety of experience in pneumatic engineering and No. 126-A describes the turbo compressor, listing more than 160 standard capacities. *Spencer Turbine Co.*

898. Ultrasonic Testing

Commercial services using reflectoscope and reflectogage are described in bulletin 50-105. *Sperry Products, Inc.*

899. Vacuum Metallurgy

Bulletin entitled "National Research Corp. and Vacuum Metallurgy" gives brief resume of the vacuum metallurgical operations and background of this company and of the research and development facilities and services available to the metallurgist. *National Research Corp.*

900. Weld-Rod Stabilizer

Four-page bulletin on low-hydrogen electrode stabilizer. Includes complete specifications of company's equipment for dehydrating mineral shielding on low-hydrogen electrodes. *Fred C. Archer, Inc.*

901. Weld-Through Sealer

Data sheet and sample of sealer that resists heat and pressure of spot welding without splattering and burning. *Minnesota Mining & Manufacturing Co.*

902. Welding

New illustrated catalog describes gun, head and wires for automatic welding. On-the-job illustrations of applications. *Air Reduction Sales Corp.*

903. Welding With Bronze

Eight-page reprint, "Jobs You Can Do With Bronze Electrodes", describes techniques and choice of bronze electrodes for welding various copper, steel and cast iron subassemblies. *Ampco Metal, Inc.*

904. Wire

Catalog 100 lists grades, sizes and compositions of standard wires and specialties such as flat wire and bookbinding and stitching wire. *Seneca Wire & Mfg. Co.*

905. Wire, Nonferrous

4-page folder contains wire gage and footage chart and information on beryllium copper, phosphor bronze, nickel silver, brass and aluminum wire. *Little Falls Alloys, Inc.*

906. X-Ray Apparatus

Illustrated booklet describes XRD-3 X-ray diffraction equipment with its variations to fit the needs of each application. *General Electric X-Ray Corp.*

907. X-Ray Inspection

Bulletin 400-520 on jib-crane unit for applications where horizontal and vertical travels of standard tubestand are inadequate. *Westinghouse Electric Corp.*

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April, 1952

674	702	730	758	786	814	842	870	898
675	703	731	759	787	815	843	871	899
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679	707	735	763	791	819	847	875	903
680	708	736	764	792	820	848	876	904
681	709	737	765	793	821	849	877	905
682	710	738	766	794	822	850	878	906
683	711	739	767	795	823	851	879	907
684	712	740	768	796	824	852	880	
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Chro-Mow®
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As a leading supplier of tubing to builders and users of radiant tube furnaces, Pressed Steel Company's assemblies dependably furnish such general features as compactness, removability, uniform heating over tube length, etc. The distinctive feature of PSC radiant furnace tubes is their light-wall construction. Installation records repeatedly show that this feature effects marked economies in fuel and furnace time. Our "light-wall" construction is based on a quarter century's experience in precision fabrication of sheet alloys.

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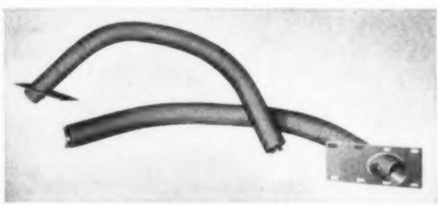

We precision assemble the most complicated designs of radiant furnace tubes. Send blue prints or write as to your needs. We fabricate heat-treat units from the complete list of alloys. You can choose the metal that is "alloy-right" for your needs.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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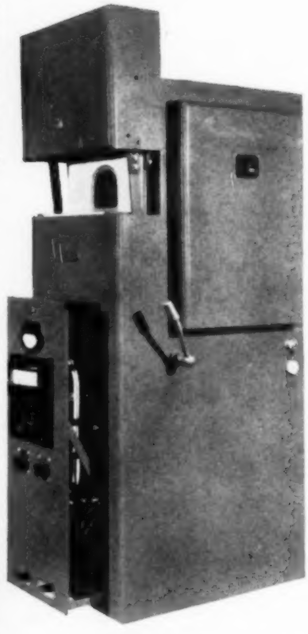
BURRELL CORPORATION

offers

NEW ELECTRIC FURNACE LINE



For information on the new Burrell furnaces, address your inquiries to Burrell Corporation, Fifth Ave., Pittsburgh 19, Pa.

...equipped with

GLOBAR Heating Elements

These new Burrell furnaces incorporate the best features of previous dual purpose models with additional new features such as the pull-out control panel shown here in opened and closed position.

As a pioneer in the development of laboratory furnaces, Burrell was one of the first to realize the advantages provided through the use of GLOBAR silicon carbide heating elements. The present line of compact Burrell Unit-Package furnaces are simple to operate and give long, trouble-free service. Heating-up time is fast... working temperatures can be changed, up or down, to suit the job. The GLOBAR elements are engineered to size and number to give most efficient service. They can be replaced speedily, from the outside, without cooling the furnace.

Burrell's experience is typical of many other manufacturers who have found that GLOBAR heating elements are excellent for a variety of diverse operations where they provide advantages in furnace design, construction and performance. We will be glad to send you complete data on GLOBAR elements upon request to Dept. MP 87-106, GLOBAR Division, The Carborundum Company, Niagara Falls, New York.

GLOBAR Heating Elements by CARBORUNDUM

TRADE MARK

"Carborundum" and "Globar" are registered trademarks which indicate manufacture by The Carborundum Company.

"I wonder what happened to me !", said Alice

ALICE in Wonderland ate the magic cake and grew until she was more than nine feet tall. Our National bureaucracy also seems to have partaken of the magic cake of power. Bureaus in our government have grown in number and scope until their activities now control, to a great extent, the lives of all individual Americans. Department after department adds more and more people -- state, justice, commerce, treasury -- not to mention those sprawling emergency born agencies of price control, N.P.A. and other alphabetical subdivisions.

The number of employees of our federal, state and local governments continues to grow. During many recent months, personnel was added to the federal payroll at the rate of 1,500 daily.

What is the reason for this mushrooming? The Korean War? Threat of war in Europe, Southeast Asia, or the Middle East? Obviously not! A glance at the federal budget gives the answer. The estimated cost of all governmental functions for the fiscal year 1952 is in excess of 70 billions of dollars, an increase of 26 billions, or approximately 60% more than last year.

When will it end? Only you, the individual citizen, who carries the bureaucratic load on his back, can stop it. It will end when enough patriotic men and women demand from congress that the Washington Wonderland start shrinking back to reasonable proportions.

YOUR SCRAP
YOUNGSTOWN
IS NEEDED

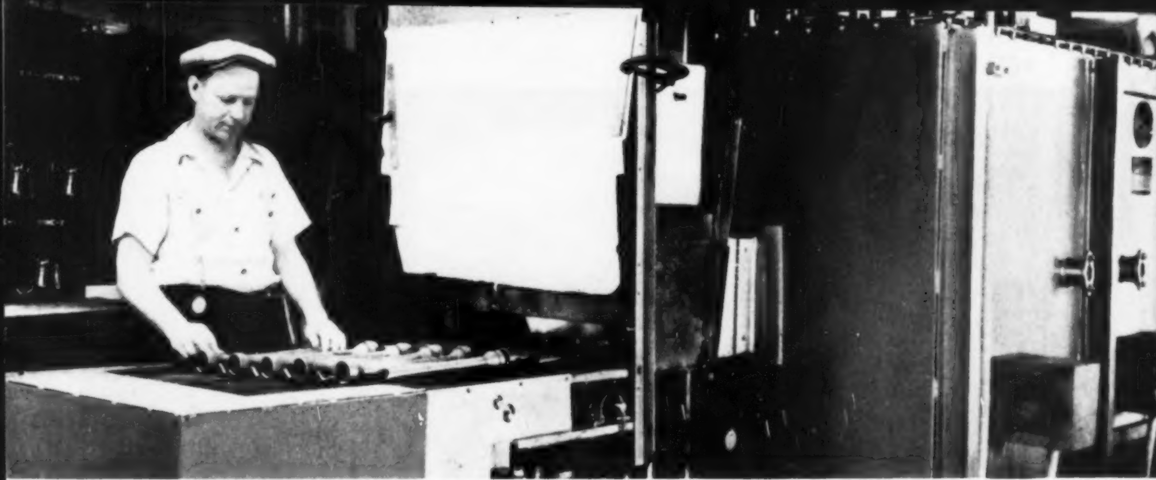
The Youngstown Sheet and Tube Company

General Offices -- Youngstown 1, Ohio

Export Offices -- 500 Fifth Avenue, New York

MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

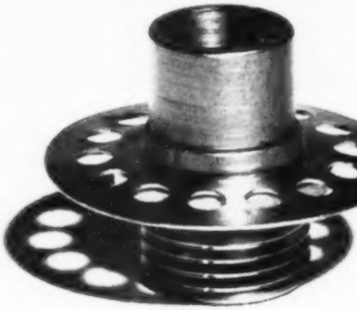
The steel industry is using all its resources to produce more steel, but it needs your help and needs it now. Turn in your scrap, through your regular sources, at the earliest possible moment.



Use G-E electric brazing furnaces and less-critical stamping, screw-machine and punching facilities to make assemblies that you now make by forging, casting or machining.

Relieve Forging and Machining Bottlenecks

Time, money, materials saved by G-E electric-furnace brazing



This 1½-ounce breather assembly for fuel-injection pumps was formerly machined from a one pound steel blank. Now a small screw-machine part and a stamping are electric-furnace brazed, reducing cost 70 per cent.

In another plant, rocker-arm assemblies were formerly cast. Now made of seven stamped parts and furnace brazed, machine work has been cut 50 per cent, weight decreased 25 per cent and cost cut 20 per cent.

It has been proved that bonds made by electric-furnace brazing have great strength and excellent appearance. This test bar, made of many ½ x ½ x ¼-inch steel blocks copper-brazed together, resists shear even when twisted 360 degrees.

LEARN MORE about electric furnace brazing for your plant. Call your G-E Sales Office, or send this coupon.

Sect. C720-72, General Electric Co., Schenectady, N. Y.

Send, for ( ) immediate project ( ) reference, the 50-page text "How and Where of Electric-furnace Brazing"—GEA-3193—to

Name..

Company..

Address..

City..State....................

GENERAL ELECTRIC

You're sighting on the moose through a Weaver Scope, made by W. R. Weaver Company, El Paso, Texas

The Superior Tube That Puts You "On Target"

Hitting specification bull's-eyes to help our customers hit their production targets is a Superior specialty.

A case in point is illustrated above. The customer, W R. Weaver Company manufactures high-quality telescopic sights for sporting and target rifles. The carbon steel tube in which the lens elements, reticule and eye piece are mounted must be strong and rigid. Tube material must have excellent machining qualities to permit fast, economical, precision working. Because salability depends a good bit on fine appearance, the tube must be extremely smooth and free from pits and scratches. This is particularly true of the larger sizes where tube ends are expanded, making imperfections more evident. Inside surface must also be smooth and to accurate dimensions.

Ordinarily you might expect tubing to fit such requirements for smoothness plus temper and machinability would be a "premium" item carrying extra charges for special handling.

Not at Superior. Here we can take the most exacting specifications in stride because of our experience and "know-how" backed by highly developed production equipment and extensive research and testing facilities.

If you have need for fine, small tubing to do a tough job well, check with us. We can probably fill your requirements from the stocks of our distributors who are located in principal cities. Write Superior Tube Company, 2008 Germantown Ave., Norristown, Pennsylvania.

BE SURE ABOUT TUBING— SPECIFY Superior

THE BIG NAME IN SMALL TUBING

All analyses .010" to ⅝" O.D.
Certain analyses (.035" max. wall) up to 1⅜" O.D.

ROUND AND SHAPED TUBING

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.

Available in:

Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095

Alloy Steels:
A.I.S.I.—4130, 4132, 4140, 4150, 8630, E-52100

Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5

Nickel Alloys:
Nickel, "D Nickel"*, "L Nickel"*, "Monel"*, "K Monel"*, "Inconel"*, 30% Cupro Nickel.

Beryllium Copper:

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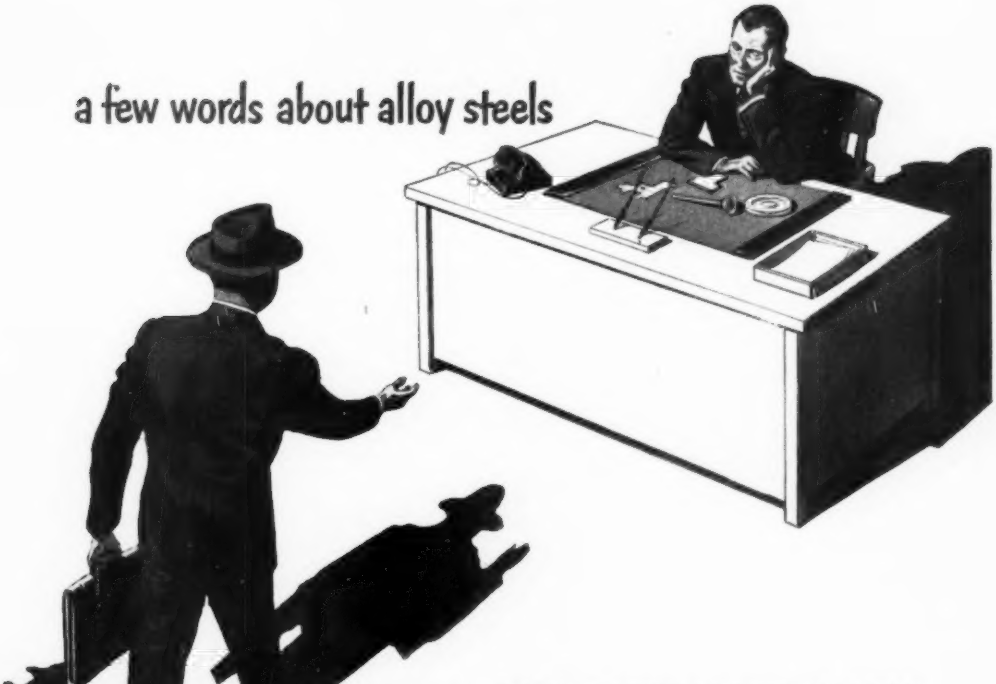
International Nickel Company

a few words about alloy steels



or...THE ALTERNATE ALLOY
that never interrupted production

This could happen to you! A customer of ours was forced by restrictions and alloy shortages to switch from the Republic alloy steel he'd been using for years to one of the alternate alloys that he could get. He'd dreaded the problems of redesigning tools and dies, of revising heat-treating procedures, of heavy reject rates while the switch was being made.

But these troubles never came!

He called upon the Republic 3-Dimension Metallurgical Service . . . the Republic Field Metallurgist, backed up by the Republic Mill and Laboratory Metallurgists. These three men worked with the customer's metallurgist and his production foreman. Together, they analyzed his requirements, recommended the best available alternate steel, worked out the way to form the steel and heat-treat it.

The shift was made with almost no interruption, and never a headache.

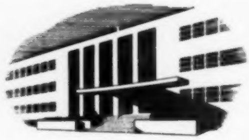
We may be able to do the same job for you . . . and to back up our recommendation with one of the many fine alloys produced by Republic . . . world's largest producer of alloy and stainless steels.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.

LAB MILL FIELD
3-DIMENSION Metallurgical Service

Republic
REPUBLIC STEEL
ALLOY STEELS

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

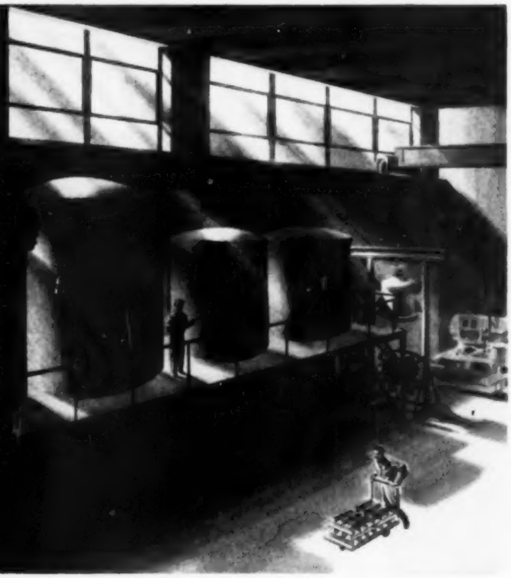


National Research Corporation

Announces

the formation of VACUUM METALS CORPORATION

U. S. A.'s Sole Commercial Source of Vacuum Melted Metals



Vacuum Metals Corporation has been formed to supply specialty metals and alloys for applications of high performance in terms of physical, chemical or electrical properties.

Vacuum melting techniques developed by National Research are used to produce metals of higher purity and alloys held to closer composition tolerances than ever before achieved commercially.

Organized by National Research as a wholly-owned subsidiary, Vacuum Metals Corporation now has facilities for vacuum melting more than five tons per day of metals such as copper, nickel, molybdenum or iron.

The unique properties of vacuum melted pure metals and alloys are particularly useful in applications such as electronic and electrical parts, magnetic materials, bearing materials, diaphragms, instrument components, laboratory standards and Atomic Energy projects.

Write to us for further information about our facilities.

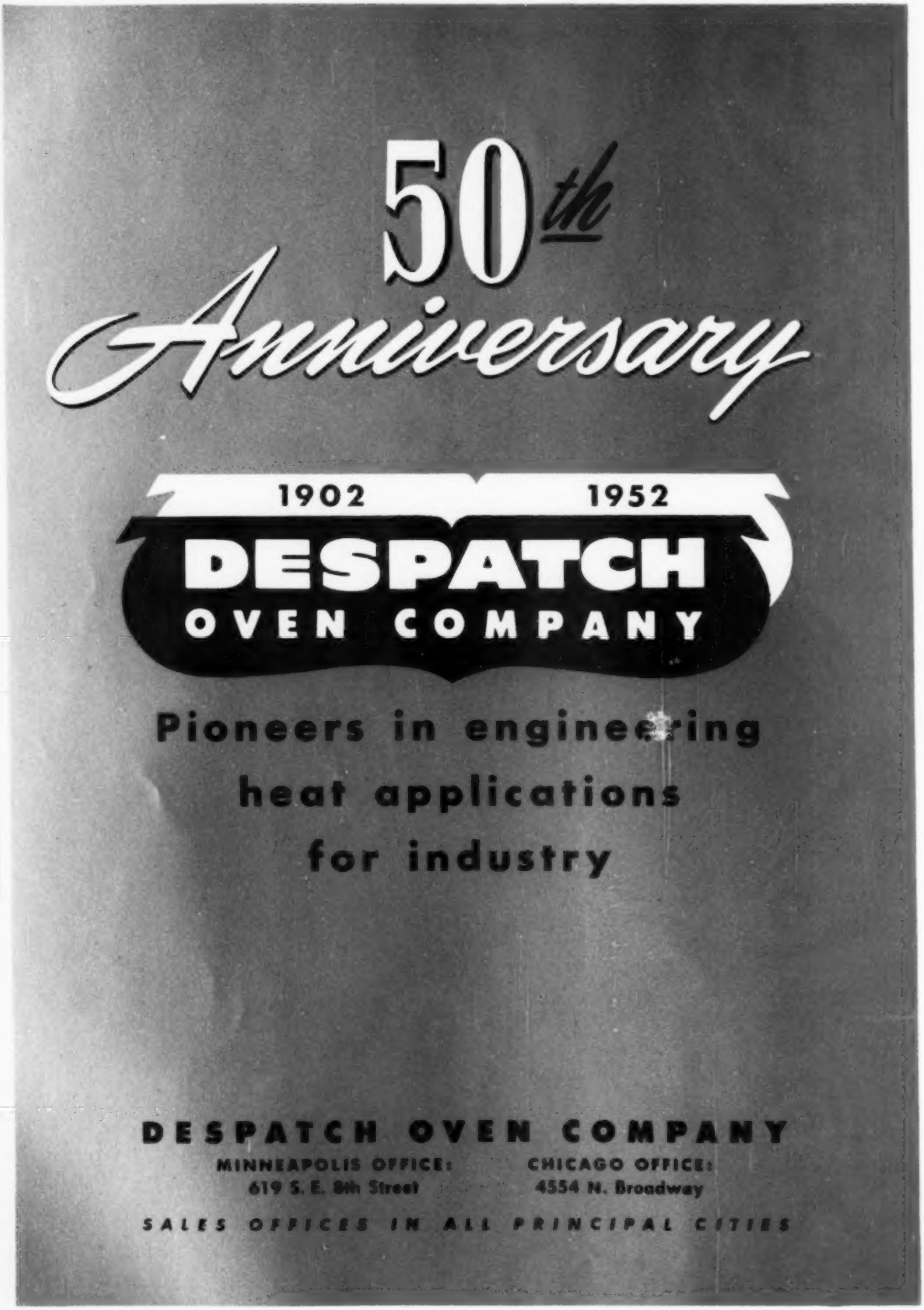
VACUUM METALS CORPORATION

Subsidiary of National Research Corporation

70 MEMORIAL DRIVE · CAMBRIDGE 42, MASSACHUSETTS

HIGH PURITY METALS · HIGH VACUUM CASTING · SPECIAL ALLOYS · GF (Gas Free) METALS


Fine steels made to order
No matter what type of special steel you order from Jessop . . . whether it be tool steel or saw steel, stainless clad or flat stock . . . you can buy with confidence knowing that it has not been picked from warehouse stock. Fine Jessop steels are tailored to your specific need. There's another thing you can be sure about when you order from Jessop. You'll get good service. Youthful, revitalized Jessop wants your business. The entire organization will work hard to bring you the degree of satisfaction that will make you a permanent customer.
HIGH SPEED STEELS · HIGH SPEED BITS · PRECISION GROUND FLAT STOCK · HIGH SPEED AND ALLOY SAW STEELS · HOT WORK DIE STEELS · COLD WORK DIE STEELS · CARBON AND ALLOY STEELS · STAINLESS AND HEAT RESISTING STEELS VALVE STEELS · STAINLESS-CLAD STEELS · CAST-TO-SHAPE STEELS · COMPOSITE TOOL STEELS · ARMOR PLATE
JESSOP
STEEL COMPANY · WASHINGTON, PENNSYLVANIA



50th
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Pioneers in engineering
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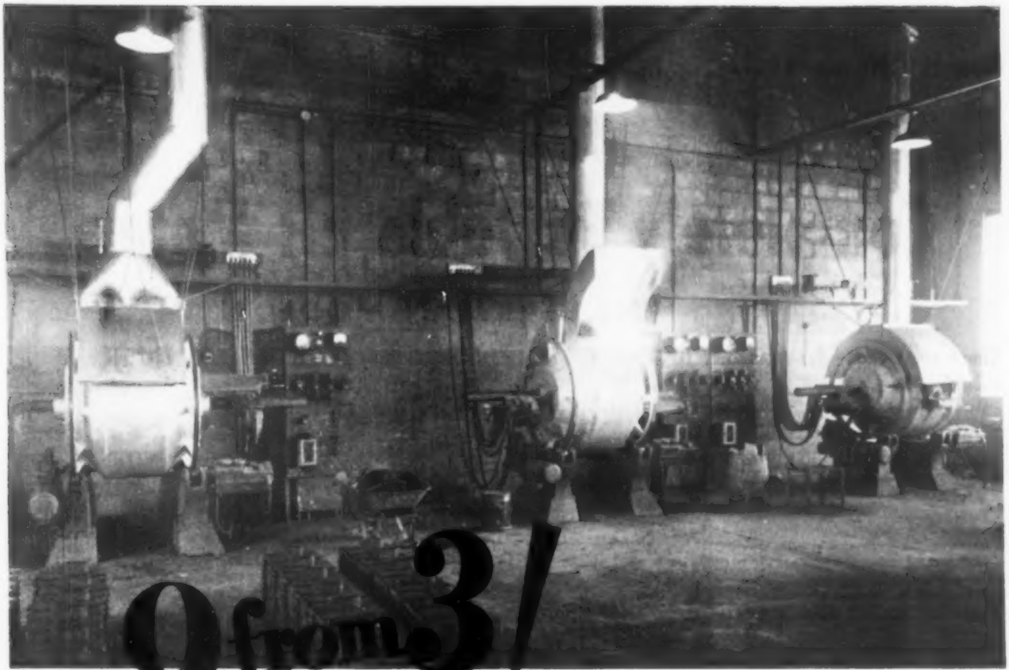

9 from 3!

NINE TONS OF HIGH QUALITY IRON PER SHIFT FROM THESE 3 DETROIT ROCKING ELECTRIC FURNACES

Vassar Electroloy Products Company has based its growth on precisely controlled, quality iron and steel castings. In five years, metal melting requirements have increased more than 700%.

Today, three 700-lb. Detroit Rocking Electric Furnaces keep the pouring ladles full, producing alloys with exact metallurgical and physical characteristics melt after melt. The fast, efficient operation of these furnaces maintains high production levels and high standards of economy.

For melting ferrous or non-ferrous metals, these indirect arc furnaces have many advantages; easy, positive control; uniformity of melts; thorough mixture of elements through the melts; optimum use of power; less metal shrinkage; more heats per day; easy shell replacement.

Furnaces are available in 10 to 4,000 lbs. capacity, designed specifically to fit your electrical specifications. Get full information. Write today!

in operation

AT ATLANTIC CITY

MAY 1-8

See this Detroit furnace in operation at our booth at the Foundry Show. It will be melting alloy iron used in an interesting shell molding demonstration by The Borden Co.

DETROIT ELECTRIC FURNACE DIVISION

KUHLMAN ELECTRIC COMPANY, BAY CITY, MICHIGAN

Foreign Representatives: in BRAZIL—Equipamentos Industrias, "Elsa" Ltd., Sao Paulo; CHILE, ARGENTINA, PERU and VENEZUELA: M. Castellvi Inc., 150 Broadway, New York 7, N. Y.; MEXICO: Cia Proveedora de Industrias, Atenas 32-13, Apartado 27A3, Mexico 6, D. F., Mexico; EUROPE, ENGLAND: Birlec, Ltd., Birmingham.

FEMA

Use it Anywhere... in the laboratory... oil field...orchard...mine... mill...food plant... Anywhere!

Completely Portable pH Meter

THE BECKMAN MODEL N

Check over these features:

- Accuracy to better than 0.05 pH.
- Low operating cost—less than 2¢ per hour.
- Built-in temperature compensation—0° to 100° C.
- Fast warm-up of less than 10 seconds.
- "Check pointer" eliminates need for frequent buffer standardization.
- Batteries are easily checked with the regular panel controls. No need to disassemble the instrument. Clip-mounting of batteries eliminates need for soldering or wiring.
- All-metal case of cast aluminum with baked enamel finish to resist wear and corrosion.
- Splash-proof design, fully desiccated internally.
- Shock-proof. Each tube is individually shock-mounted.
- Weighs less than 8 lbs., complete.
- Equipped with the new Beckman Red Label Glass Electrode—virtually unbreakable, covers almost the entire pH range, usable from freezing to boiling.
- By far the most rugged overall construction of any pH meter.

The new Beckman Model N pH Meter is entirely independent of any outside power circuit. It meets perfectly the wide demand for a completely portable battery operated pH instrument that is inexpensive, light in weight, compact, and rugged enough to be used anywhere. The newly developed Beckman Model N not only meets all these requirements, but many more. For instance, the electrode support rotates alongside the case for maximum convenience in carrying. Instrument can be used in either horizontal or vertical position. Convenient controls not only centralize all operating functions, but also permit checking amplifier circuits and battery condition without opening case or disturbing battery connections.

Two Models are Available:

1. Model N-1 (illustrated), without a cover but with a rigid handle—12 inches long, 4½ inches deep, 7½ inches wide including electrodes. Complete with glass and reference electrodes, electrode holder, 50 ml beaker, buffer solution, 100 ml KCL solution, 100 grams KCL crystals.

2. Model N-2 (not illustrated), with a cover-compartment hinged to the case with spaces for 2-ounce bottles of buffer solution and distilled water, thermometer, electrodes and beaker—12 inches long, 8 inches deep, 7½ inches wide including electrodes. Complete with the same accessories as listed above for Model N-1 and in addition, thermometer 0-100°C, polyethylene bottles for buffer solution and distilled water.

H-29601—Beckman Model N-1 pH Meter. Each **$180.00**

H-29602—Beckman Model N-2 pH Meter. Each **$195.00**

(Quantity prices on request)

For further information on these instruments or any other Beckman product, contact the Harshaw Scientific office nearest you.

HARSHAW SCIENTIFIC
DIVISION OF THE HARSHAW CHEMICAL CO.
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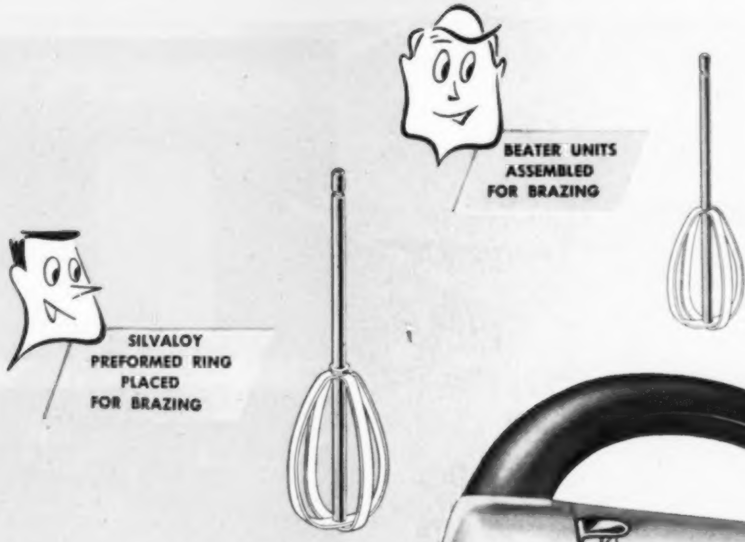

SILVALOY

In the production of Mixette beaters, preformed Silvaloy 45 rings and APW 1200 Flux are used to keep production at an economical top-speed level and to assure maximum strength in the joint. The assembly is brazed with induction heat.

HAMILTON BEACH MIXETTE BEATERS PROTECTED FOR QUALITY AND PRODUCTION

The famous Hamilton Beach name is a well-respected guarantee of quality in consumer markets. As with other successful manufacturers, quality in terms of design, materials and production is of utmost importance.

Silvaloy Brazing experts are successfully helping to improve results, increase production and lower costs for many thousands of manufacturers. We would like to have you make all possible use of this valuable technical service—without obligation. Call or write. A Silvaloy technician will visit your plant at your convenience.

SILVALOY SILVER BRAZING ALLOYS ARE SUPPLIED FROM STOCK THROUGH A RELIABLE DISTRIBUTOR IN YOUR AREA.

FREE SEND FOR THIS 48-PAGE "COMPLETE GUIDE TO SUCCESSFUL SILVER BRAZING!"

THE AMERICAN PLATINUM WORKS

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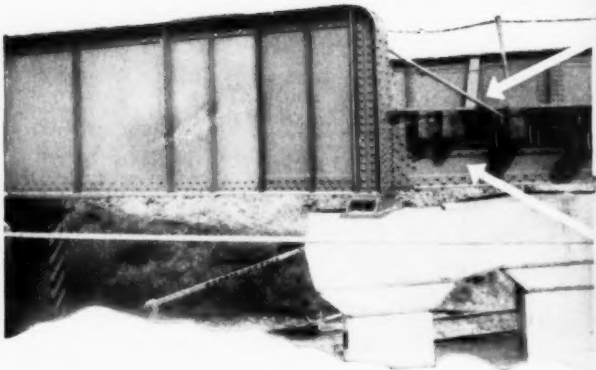
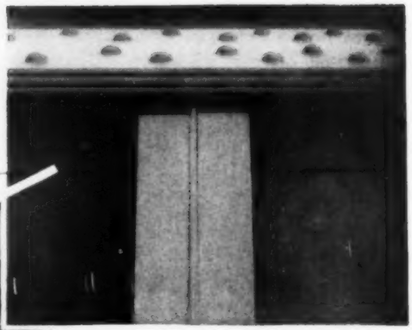
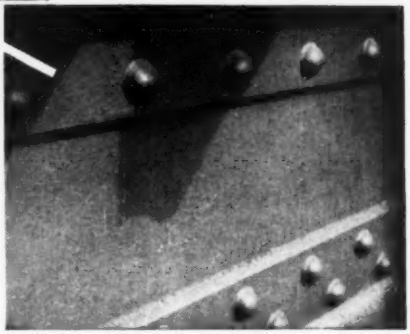


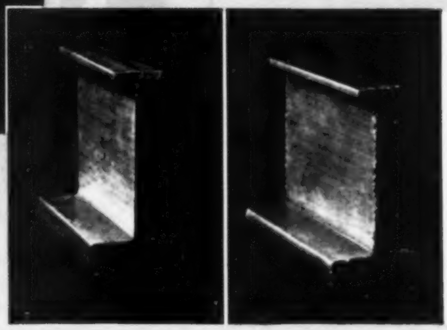




NEW! Johnson's STIK-WAX

An entirely new kind of lubricant that

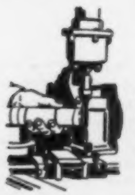
outperforms grease sticks, tallow, bar soaps!



Sawed sections of aluminum extrusion. Left: section sawed with Johnson's No. 140 Stik-Wax is burr-free. Right: section sawed with grease stick shows bad burr.

On grinders
Stik-Wax lubricates to reduce heat—wheel clogging.

On belt sanders
Stik-Wax lubricates to give better finish—longer belt life.



On taps
Stik-Wax lubricates to cut smoother threads — increase life of taps.

On band or circle saws
Stik-Wax lubricates to lengthen blade life—gives smoother cuts—reduces burns.

Johnson's No. 140 Stik-Wax is the new wax lubricant that outperforms grease sticks, tallow, bar soaps. Saves materials and tools . . . saves time . . . produces higher quality work.

Exhaustive tests have shown that the performance of Johnson's No. 140 Stik-Wax far exceeds that of ordinary lubricants for drilling, grinding, sawing, tapping, spinning and pipe cutting. Taps and drills last far longer. Saws and cutters need sharpening much less frequently. Sanding belts and disks get added life . . . give cleaner, smoother finishes.

Applied manually or automatically, there is no end to the metal working lubricating jobs that Stik-Wax will do *better* to *speed* jobs . . . *add life* to equipment.

A product of JOHNSON'S WAX Research

Test STIK-WAX in your plant— **FREE!**

Industrial Products Dept. MP-4
S. C. Johnson & Son, Inc.
Racine, Wisconsin

Please send free sample of Stik-Wax for testing . . . also send complete information and instructions for use.

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Manufacturers

LOOK FOR THIS SIGN

on the profit road . . .

Your profit for tomorrow will be decided by the work you produce today.

Keep every production line running with fewer breakdowns and less replacements by using ACCOLOY Heat and Corrosion Resistant castings.

The improved designs, finer grain size, the close control of pouring and the multiple testing of each finished piece, all contribute to the longer service life of these castings.

As a manufacturer using trays and fixtures, carburizing boxes, salt pots, retorts, muffles or roller rails — *make an investment now that will keep you posted on the profit side of the ledger.*

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ALLOY ENGINEERING & CASTING COMPANY

ALLOY CASTING CO. (Div.)

CHAMPAIGN • ILLINOIS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

Park Chemical Company

BY THE *Research Laboratory* OF THE PARK CHEMICAL CO.

DETROIT 4, MICHIGAN

Tests Show New Quench Oil has Intensified Triple Action

PARK'S Triple A Quench Oil has intensified triple action: 1. Rapid heat removal with faster cooling rate in the critical range giving higher and deeper hardness. 2. Slow cooling through the hardening range, minimizing distortion. 3. Great stability due to special anti-oxidants. Result is longer life and bright quenching properties.

An explanation of the quenching process illustrates how Park Chemical Company with over forty years of chemical and metallurgical background developed an ideal oil to fit the ever mounting production quenching problems.

Three stages of cooling are observed when steel is quenched in oil from a red heat. (A) Formation of a vapor film at the steel surface; cooling is accomplished by conduction and radiation through this vapor film and is relatively slow. (B) Direct contact of the oil with the metal surfaces causing a boiling action which continually dissipates the vapor film formed and results in rapid cooling. (C) After the metal has been cooled to the boiling point of oil, vapor is no longer formed; cooling is by conduction and convection, and the metal slowly cools to the temperature of the oil.

Although water and water solutions provide high cooling rates throughout these three stages of quenching, they are often impractical because rapid cooling is not desirable in the lower ranges of temperature where martensite is formed. It is at this time that temperature differentials within a piece of steel cause warping and cracking. Thus oil quenching is preferred for all steels possessing sufficient hardenability to avoid transformation to soft structures in stages A and B, since the cooling rates furnished by oils during Stage C are ideal for preventing temperature differentials.

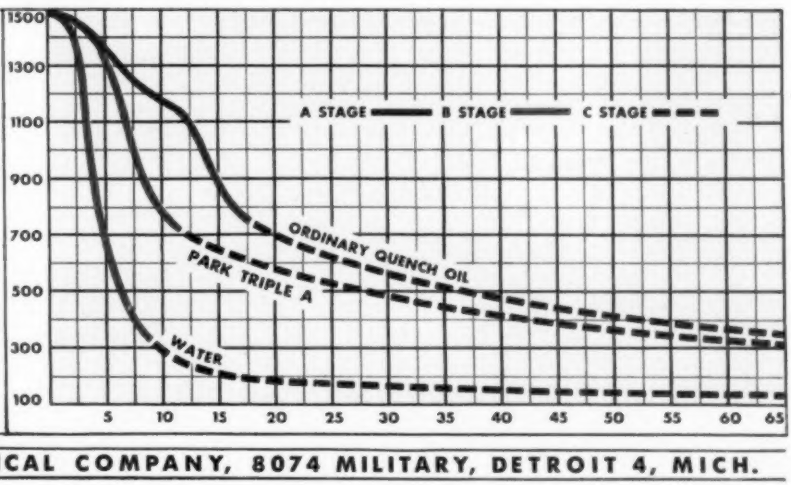
It is apparent that any improvement in the cooling power of oil in Stages A and B would be most desirable. Such improvement is obtained in water quenching by the addition of salt or caustic soda. The brine or caustic solution has a wetting action which completes the quenching job faster than fresh water. Fresh water takes hold only in spots causing non-uniformity. Brine solutions provide deeper and more uniform hardnesses. It seems logical to attempt to do this same thing with oil. The mineral intensifiers added to Park's Triple A Quenching Oil act in this manner.

The accompanying cooling curves serve to illustrate how this additive has altered the quenching power of the oil in the A and B stage, yet has retained the desirable slow cooling in the C stage.

This is the front page of a 4 page Technical Bulletin on Oil Quenching. For the complete bulletin write for Bulletin F-8.

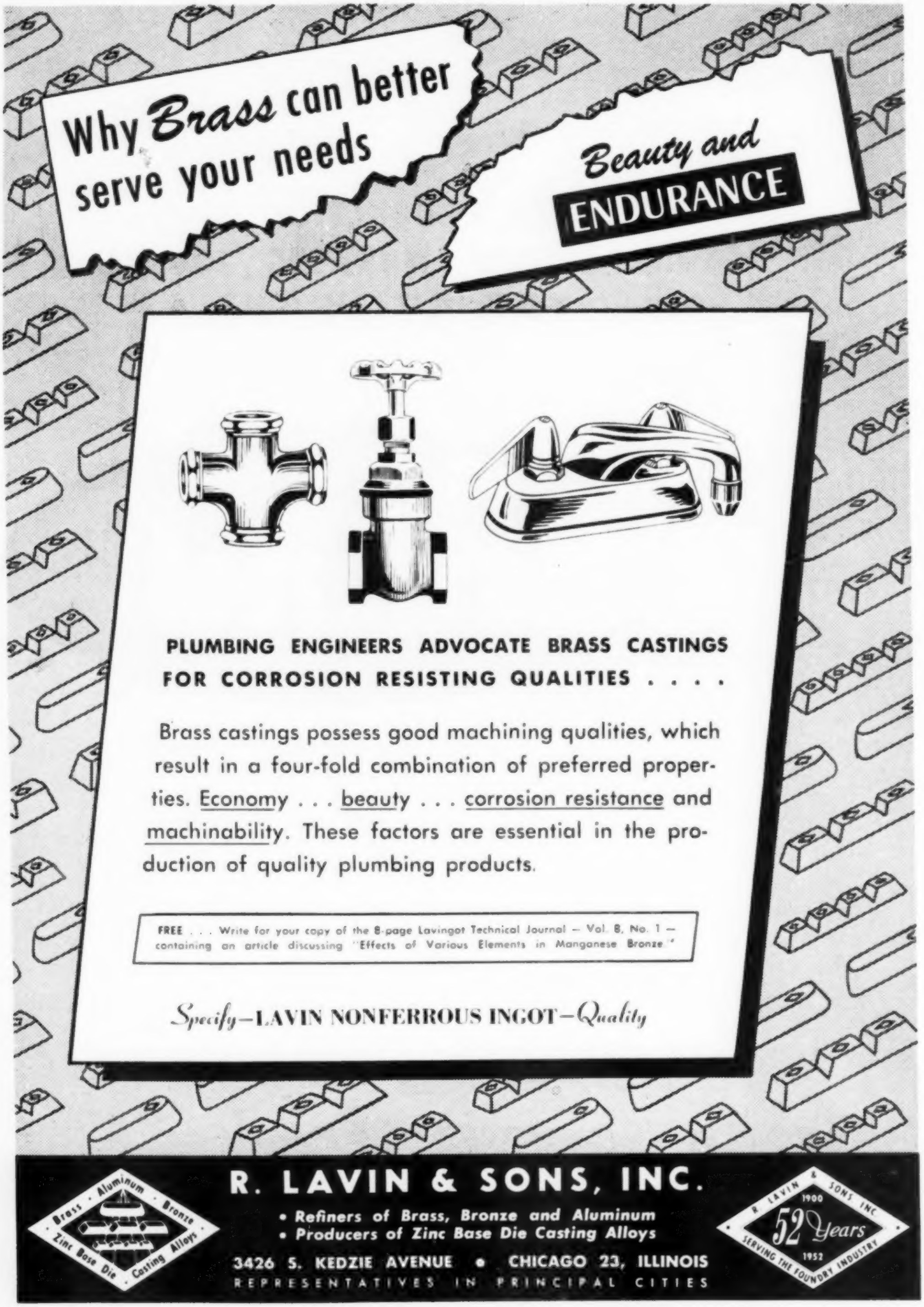
A, B, C, stages in cooling curves showing advantages of Park Triple A Quench Oil. Samples quenched from 1500° F. in oil at 140° F. and water at 70° F. Steel SAE 1045 ½" dia. x 2" long.

Note: Chart is plotted in degrees F. on the ordinate and time in seconds on the abscissa.



PARK CHEMICAL COMPANY, 8074 MILITARY, DETROIT 4, MICH.


STEEL MINE
If American industry will "mine" its dormant scrap—the obsolete and worn-out machinery and equipment hidden, overlooked and forgotten in its plants and yards—present record-high steel production can continue.
INLAND STEEL COMPANY
38 South Dearborn Street
Chicago 3, Illinois


Why Brass can better serve your needs
Beauty and ENDURANCE
PLUMBING ENGINEERS ADVOCATE BRASS CASTINGS FOR CORROSION RESISTING QUALITIES . . . .
Brass castings possess good machining qualities, which result in a four-fold combination of preferred properties. Economy . . . beauty . . . corrosion resistance and machinability. These factors are essential in the production of quality plumbing products.
FREE . . . Write for your copy of the 8-page Lavingot Technical Journal — Vol. 8, No. 1 — containing an article discussing "Effects of Various Elements in Manganese Bronze."
Specify—LAVIN NONFERROUS INGOT—Quality
Brass · Aluminum · Bronze · Zinc Base Die Casting Alloys
R. LAVIN & SONS, INC.
• Refiners of Brass, Bronze and Aluminum
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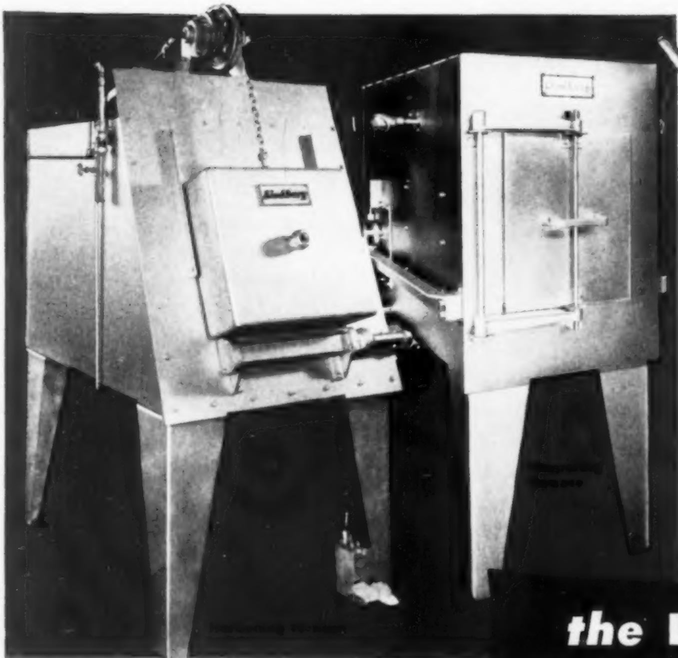
REPRESENTATIVES IN PRINCIPAL CITIES
R. LAVIN & SONS INC 1900 52 Years 1952 SERVING THE FOUNDRY INDUSTRY



BASIC FOR EVERY TOOLROOM

the LINDBERG TOOLROOM TEAM

When production depends on tools and dies, tools and dies depend on the LINDBERG TOOLROOM TEAM—a basic requirement in every toolroom—a must where you want the ultimate in tools and dies which will keep your production rate up and your machinery running with a minimum of tool and die failure. The LINDBERG TOOLROOM TEAM gives you the precision heat treating which your precision tools and dies need for lasting performance.

LINDBERG HARDENING FURNACE—eliminates finishing due to scale and decarb with simple accurate atmosphere control.

LINDBERG TEMPERING FURNACE—allows you to obtain the exact "Rockwell Hardness" required for each specific tool or die.

For tools and dies requiring high speed tool steel—investigate the Lindberg "L" Type combination preheat—high heat Furnace.

LINDBERG FURNACES

Specify **LINDBERG**

LINDBERG ENGINEERING COMPANY W. Hubbard Street, Chicago 12, Illinois

This heat-treating record ...is NEWS

The above chart shows a record of surface carbon control during four types of heat-treating processes. During three of these operations carbon is added; during the fourth, it is accurately maintained.

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Metal Progress

Vol. 61, No. 4 • April 1952

 Published monthly; subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $2.00. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, under the Act of March 3, 1879 . . . The American Society for Metals is not responsible for statements or opinions printed in this publication . . . Requests for change in address should include *old* address of the subscriber; missing numbers due to "change in address" cannot be replaced. Claims for nondelivered copies must be made within 60 days.

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Floyd E. Craig, *Art Director*

This month's cover design, representing various types of wire fencing and mesh, is by Roland Jelarcic. Unfortunately credit was given to Mr. Jelarcic for last month's very handsome cover, representing a dipper-load of iron ore, whereas it is actually the work of Edwin Axel, currently a student at the Cleveland Institute of Art.

Technical Articles

Correspondence

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Abstracts of Important Articles

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By John C. Redmond, Vice-President, and John W. Graham, Research Engineer
Kennametal, Inc., Latrobe, Pa.

Field of Cemented Carbides Expanded by Titanium Compositions

The continuous progress of industrial technology has created a demand for new materials of unusual physical properties. Cemented tungsten carbide is one such material that has been engineered into many industries where high hardness and resistance to wear are required. Its development still continues, and new fields of application are opened every day. It is not generally realized, however, that cemented carbides are a large class of materials based on compounds of carbon and metals other than tungsten that greatly extend the range of properties offered. New compositions are now becoming available which further enlarge their importance.

A new group of cemented carbides based on titanium has been available for service testing for more than three years. They were developed by Kennametal, Inc., and are sold under the trade name Kentanium.

Extensive tests have shown that while the titanium carbides are basically similar to tungsten carbide in such properties as high modulus of elasticity, hardness and resistance to wear, low thermal expansion, and many other characteristics, they possess additional properties which greatly extend the traditional fields of carbide applications. Their resistance to oxidation combined with high strength gives promise for service at temperatures far above the range where "superalloys" are now used. Their low density is a further advantage at high temperature and also in many applications at ordinary temperatures where weight is a factor. These advantages are obtained with a minimum of so-called strategic elements. These new carbides will replace present materials in many applications and can be built into equipment and processes operating under conditions heretofore considered impossible.

Accompanying developments in fabrication techniques permit the manufacture of larger and more complex pieces to close tolerances and in large volume. These methods will be discussed later.

Kentanium is made by procedures similar to those used for "Kennametal" (tungsten carbide compositions). Its principal ingredient is pure titanium carbide. Cobalt was the first auxiliary metal used but it has since been found that nickel is superior. Iron is sometimes useful. Small percentages of columbium, with or without tantalum as a pure carbide, are also added. The ingredients are ball milled together to very fine particle size, pressed as near to the desired shape as possible, given further shaping as required with or without pre-sintering, and then sintered out of contact with air. During the latter step a large but controllable shrinkage occurs.

The general properties are compared with tungsten carbide and superalloys in Table I. For purposes of this table, the grades with 10 to 30% nickel as the auxiliary metal have been grouped together.

The low density of titanium carbide in comparison with the superalloys is immediately apparent. In rotating parts the centrifugal stresses are in proportion to the material's density; thus the stress from this component on Kentanium would be about two thirds that developed on the superalloys.

Hardness is high, thereby indicating good wear resistance. Certain applications to be described later indicate that a large amount of the hardness is retained at high temperature. Likewise, compressive strength is high and remains high in a great degree at temperatures where refractory alloys deform plastically.

Young's modulus approaches that of cemented tungsten carbide and is about double that of ferrous alloys and superalloys. This of course means approximately half the elastic movement developed on alloys for a given stress.

Electrical resistance is intermediate between conductors and resistors. The re-

Properties of Titanium Carbide

sistance increases with temperature, corresponding to changes in metallic thermal conductivity, thereby indicating that the material has definite metallic characteristics.

Thermal conductivity of titanium carbide is superior to that of the superalloys. This, together with low thermal expansion, accounts for the superior performance of titanium carbide over high-strength refractory oxides in the many thermal shock tests which have been made.

Thermal expansion of titanium carbide is a straight-line function of temperature. This is related to the stable phases characteristic of the material at 1800° F. and above. Heat treating is unnecessary, and the strength at high temperatures is an inherent property of the titanium carbide phase.

Kentanium retains more of its tensile strength as temperature is increased than do most of the refractory alloys. In laboratory tests, it was found that one of the TiC compositions was superior to a well-known refractory alloy above 800° F., on the basis of tensile strength – weight ratios.

Tensile tests, however, do not provide a conclusive comparison, especially when the carbide must undergo a high tensile stress for a long period of time at high temperatures. A more significant method is the stress-rupture test, which relates the variables of temperature, tensile stress, and time of failure. Figure 1 shows several stress-rupture curves for grades K151A and K152B at various temperatures, as well as for Inconel "X" (which exhibits some of the best properties obtainable in alloys). Several conclusions can be drawn from this chart.

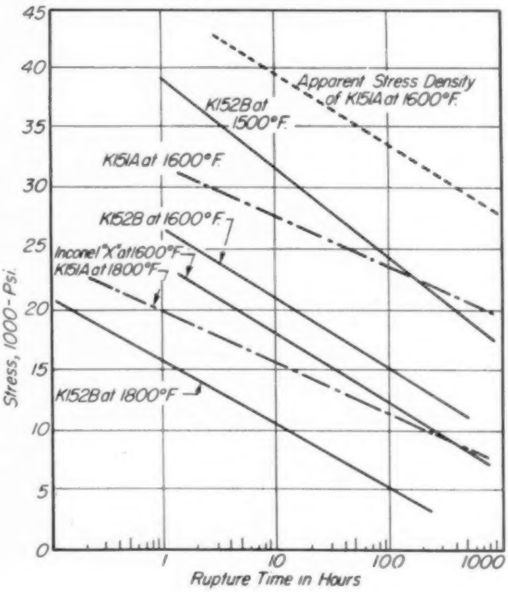
First, it is obvious that cemented titanium carbide is like metal in that resistance to steady stress decreases with increasing temperature. Most of the commercially available heat resistant alloys contain unstable phases above 1500 or 1600° F., and this usually results in a great loss of strength at these temperatures. Evidence shows that the Kentanium materials retain a great proportion of their inherent strength at a temperature several hundred degrees above the range where metallic alloys operate satisfactorily. Figure 1 shows that K152B has about 125% and K151A has about 170% the stress-rupture strength of Inconel "X" at 1600° F. If time is taken into consideration, it can be seen that K151A would last more than 100 times as long as Inconel "X" at 1600° F. and equal stress.

Another factor particularly applicable to rotating parts is the apparent stress-density advantage. As shown earlier, a Kentanium part would develop about two thirds the stress of an alloy part of the same size and shape rotating at the same speed. This would increase the apparent stress-rupture advantage of Kentanium K151A over Inconel "X" about 44% at 1600° F. The upper dashed line in Fig. 1 shows this relationship. It is figured on the basis that the apparent centrifugal stress in a rotating part is proportional to the density of the material. In the figure, apparent stress equals the actual stress in K151A multiplied by the ratio of densities, Inconel "X" to K151A.

All other factors being equal, a rotating K151A part should last about 10,000 times as long as an Inconel "X" part at 1600° F. Later stress-rupture tests on K151A indicated that its strength and life advantages over Inconel "X" and other alloys are even greater than this.

Work now under way indicates that high-temperature stress-rupture strengths of newer

Fig. 1 — Stress-Rupture Curves for Kentanium, Grades K151A and K152B, as Compared to Inconel "X"



compositions may possibly be doubled over the strengths reported here. It also appears that compositions can be produced containing no strategic metals and with stress-to-rupture properties equaling those of the currently used superalloys which are high in strategic elements. Oxidation resistance would probably be adequate.

Oxidation resistance of the commercially produced compositions is adjusted to the requirements of the application. Those grades having the best oxidation resistance form a tenacious and impervious oxide coating in a short time. Small additions of a complex carbide containing columbium, tantalum and titanium reduce the oxidation to a decreasing parabolic rate.

Oxidation resistance of various grades in air at 1800° F. for 118 hr. are as follows:

GRADE	OXIDATION
K138	0.0077 in.
K138A	0.00095
K151A	0.00085
K152B	0.00115

These figures represent the increase in thickness of a thin specimen due to oxide growth on one surface upon heating in an unsealed electric furnace. Improvement of the last three is due to the presence of small amounts of a complex carbide of columbium, tantalum and titanium.

The ductility of the titanium carbide compositions that have been tested is low. The stress-rupture elongation at 1600° F. has seldom been over 2% and is slightly greater at higher temperatures.

Fabrication of Shapes

Improved powder metallurgy and sintering techniques have been developed. As mentioned previously, pure carbide and metal powders are ball milled together under closely controlled conditions. The milled powders are pressed into blocks or ingots having uniform density. The ingots are pre-sintered to the consistency of chalk and, though friable, have enough strength for handling and machining. Large symmetrical round shapes can be turned in a lathe with diamond-tipped tools. Complex shapes such as the turbine impeller shown in Fig. 2 are machined with abrasive wheels by means of usual methods and setups with minor modifications. Milling cutters are usually replaced by high-speed abrasive wheels. Turbine blades and nozzle vanes are machined in large lots on multiple-head automatic machines.

After such machining to shape, the pieces are sintered at high temperatures; allowable shrinkage usually brings the pieces to within 1% or closer to size. If necessary, final design tolerances to within 0.0001 in. can be met by grinding, using diamond and silicon carbide abrasive wheels on standard tool grinding machines. Other fin-

Table I — Comparative Physical Properties of Cemented Carbides

PROPERTY	TiC *(a)*	WC *(b)*	SUPERALLOYS *(c)*
General Properties at Room Temperature			
Density, g. per cc.	5.5 to 6.5	11.90 to 15.10	8.3 to 8.7
Hardness, Rockwell A	83 to 93	85 to 93	61 to 65
Modulus of elasticity	55×10^6 *(d)*	61 to 90×10^6	30×10^6 *(d)*
Compressive strength	550,000 psi.	518,000 to 800,000 psi.	—
Conductivity			
Electrical *(e)*	1.9 to 5	4.3 to 9.4	1.37 to 1.8
Thermal *(f)*	0.075 to 0.085	0.068 to 0.207	0.035 to 0.065
Properties at Elevated Temperature			
Thermal expansion *(g)*	4.5 to 5.0	2.5 to 4	6.73 to 8.5
Oxidation resistance at 1800° F.	Excellent	Poor	Good
Tensile Strength			
at 70° F.	80,000 to 100,000 *(h)*	Note *(i)*	110,000 to 180,000 *(j)*
at 1500°	55,000		52,000 to 73,000
1600°	47,000		34,000 to 51,000
1800°	40,000		9,000 to 25,500
2000°	30,000		13,100
2200°	12,500		—
2400°	3,000		—

Notes

(a) Trade name "Kentanium"; composite properties of grades using 10 to 30% nickel as the auxiliary binding metal, grades K150A, K151, K151A, K151B, K152 and K152B.
(b) Trade name "Kennametal".
(c) Range for several Co-Cr-Ni and high-Ni alloys.
(d) Representative values.
(e) Percentage of copper standard.
(f) Calories per cm. per sec. per °C.
(g) Inches/in./°F. $\times 10^{-6}$ at 1200° F.
(h) Not yet fully established.
(i) No tests are available.
(j) *Metal Progress* data sheet, November 1951, p. 80-B.

ishing methods are being developed. Many complex shapes can be made to such accuracy that no final grinding is required.

Our company has also improved an extrusion technique which produces both titanium carbide and tungsten carbide shapes such as tubes, rods, bars, flats and even objects having complex geometrical cross section.

These manufacturing techniques lend themselves handily to economical volume production of shapes formerly believed too complex to manufacture. Scrap losses from these processes are negligible and material recovery is high.

The properties of Kentanium have been unfamiliar to most metals engineers. In spite of this, various compositions are being introduced into a wide variety of applications. Two of the most promising and perhaps most important are turbine blades and nozzle vanes for jet engines. Another important potential use is in the aircraft industry for valves in high-powered reciprocating engines.

One of the first applications was in spinning tools for hot metal where high strength, wear resistance and good oxidation resistance are requisite. The material is also suitable for tools for trimming flash from hot forgings or pressings.

Small-diameter Kentanium balls having the above characteristics plus a high compressive strength are ideal for hot hardness testers. Other high-temperature test machines use cemented titanium carbide as compression dilatometer heads, tensile test heads, pressure sleeves, and anvils for high-temperature transverse rupture tests. Development work is now in progress on hot forging dies used in the forming of refractory alloys.

Fig. 2 — Titanium Carbide Turbine Impeller Designed to Operate at Inlet Temperature of 2000° F.

An example of another severe application is a pressure reaction vessel shown in Fig. 3 which has repeatedly withstood internal pressures of 30,000 psi. at 2300° F.

Fig. 3 — High-Temperature Pressure Vessel 18 In. Long Withstands 30,000 Psi. at 2300° F.

A successful room-temperature application is for gage rings that are ground to close tolerances which must be maintained over long periods against abrasion and other material abuses. This is an instance where low density combined with wear resistance is highly advantageous.

Another application in which high-temperature properties are not involved is balls for oil well pump valves. In addition to wear resistance and light weight, resistance to severe corrosion is often required. Promising field results have already been obtained.

Proper design is as essential in the use of cemented titanium carbide as with any other new material. The high modulus of elasticity and the accompanying low ductility usually require changes in design to replace more ductile materials. Titanium carbide can be brazed when required, but mechanical joints are preferred. Radii in highly stressed parts must be as large as possible. Where severe thermal shock is involved, section thicknesses must be as uniform as possible. Other properties must be taken into account in specific design problems.

Thus, there is ample evidence that titanium carbides greatly extend the range of usefulness of cemented carbides and enlarge the possibilities for engineering design.

By Harold J. Roast, Foundry Consultant, London, Ont.; Consulting Editor for Metal Progress

An Appraisal of the Shell Molding Process

A new shell molding process has recently attracted much attention from American foundrymen, so that the general scheme is fairly well known. Briefly, warm metal pattern plates or core boxes are utilized. A fine granular mixture of sand with a little thermoplastic is poured into the mold box; the resinous binder softens and the mass seeks the contour of the pattern; within seconds a thin, putty-like layer is formed and the superabundant mixture can be dumped. The pattern plate is then heated about 1 min. at 600° F., whereupon the cured (hardened) investment can be lifted off by suitable means. Half molds (with hollow cores) made in this way and containing necessary gates and risers are then bolted together, embedded in metal shot, and poured. The investment (sand plus resin) is destroyed during shake-out, but the metal shot is reclaimed for reuse.

Interest in this Croning or "C" process arose after it had been briefly described by Wm. W. McCulloch in a postwar report on German technology (F.I.A.T. report No. 1168, U. S. Government Office of Technical Services, Washington), and had shortly thereafter benefited from the publicity accompanying sale of "patent" rights. McCulloch's observations were made in the Hamburg plant of Johannes Croning & Co. It was also understood that components for some 6000 hand grenades were made daily by this process at Haller Werke in Hamburg. The New York Naval Shipyard started experiments in its material laboratory in 1947 to devise the best ingredients and techniques and to evaluate the castings so produced. While much work has also been done by the American foundry industry, it has been shrouded in secrecy due to the clouded patent situation, so that the technical information is contained in publications by Navy metallurgists, notably Bernard M. Ames, Seymour B. Donner, and Noah A. Kahn. The three published "Metallurgy of Shell Molding" in *American Foundryman* for January 1952, and "Plastic Bonded Shell Molds" in *Foundry* for August 1950. Mr. Ames presented a supplementary discussion on "Shell Molding" before the Malleable Founders' Society on Sept. 20, 1951.

The writer had an opportunity to observe the process during a recent visit to the New York Naval Shipyard at Brooklyn, and to discuss the details with Mr. Kahn, head metallurgist; Mr. Ames, senior metallurgist; and Mr. Donner, associate metallurgist; as well as Capt. H. T. Koonce, U.S.N., director of material laboratory, and Charles E. Fraser, superintending engineer.

The object of my visit was to assess the practicability of shell molding, and to evaluate the evidence supporting the belief that it is likely to be a really useful addition to the foundry industry. The definite answer to this question is yes, in the opinion of the writer, even though it must be borne in mind that any statements made concerning a brand-new process are liable to drastic modification as it is gradually perfected.

General Requirements

Alloys best suited to shell molding seem to be cast, malleable, and nodular irons, manganese and aluminum bronzes, aluminum alloys, magnesium alloys, silicon bronzes, tin bronzes of low lead content (5% max.), and alloy steels. With magnesium alloys there is no need for inhibitors in the molding materials, such as are used for ordinary sand castings. Further improvement is required before low-carbon steels and high-lead bronzes can be classed as suitable. The former tend to have relatively rough surfaces, the latter to sweating out of the lead component.

While there is no obvious limit to the size of casting that might be made, in the present pioneering stage, castings up to 50 lb. are considered practical. However, cost will enter into the picture, since really large

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castings are generally not ordered in sufficient quantity to justify the pattern expense.

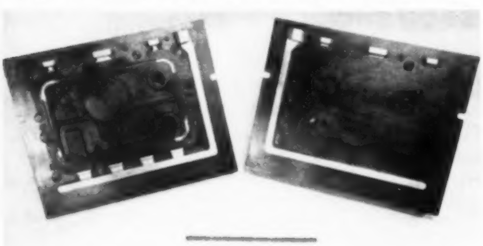
A principal requirement for practical use of shell molding is that a sufficient number of castings be made from any given pattern to justify the cost of the metal pattern plate. The process may also be advantageous where expense can be saved by the reduction or complete elimination of machining cost, together with greater dimensional accuracy. The saving of machining cost is particularly important with alloys generally considered hard to machine. In such instances, a much smaller number of castings from the pattern plate may justify use of the process.

Tolerances compare favorably with the lost-wax investment process and plaster molding in castings of equally large size. For example, plates 18 x 12 in. with bosses and cored holes can readily be made within a tolerance of 0.003 in. per lineal inch. At the same time the process is simpler in operation, once the metal pattern has been accurately made. (Of course, investment casting requires the preliminary manufacture of a metal mold of high precision in which the wax or plastic model is made.)

Figure 1 shows a metal pattern plate used for shell molding. A requirement of the metal is that it shall not be distorted upon repeated heating, even to 1000° F. — the temperature required for curing certain desirable thermoplastic mixtures. This temperature also eliminates the possibility of repairing or adjusting the pattern plates with the fusible solders ordinarily used. Suitable pattern plate materials, therefore, are alloy cast iron of the kind intended for high-temperature use, or the "nonshrink" and "graphitic" steels. Still other alloys may be found suitable as future experience dictates.

Gating (and risering if required) follows the conventional methods used for ordinary sand molding, with bottom gating given the preference. The mold material used is more insulating than foundry sand, and the risers can therefore function more effectively, since a better opportunity is provided for those parts of the casting that cool first to secure molten metal. There is no advantage to be had from the steel shot, as far as thermal conductivity is concerned. Replacing steel shot with copper shot does not influence the grain size of the casting (all other things being equal); in fact, comparison castings made in green sand have much finer grain size.

Fig. 1 — Master Pattern Plate Used in Shell Molding



Formulation of the mold material is, of course, a most important factor. It consists essentially of a high-grade silica sand of subangular grain class (say 92 to 95%) with some 8% or less of pulverized resin capable of heat polymerization. The ingredients may be mixed in an ordinary Simpson muller, but it is desirable to cover the muller to prevent the escape of fine dust. In a large installation it would probably be desirable to exhaust the dust by a suitable suction connection to an elementary small baghouse. It has been suggested that the charges of static electricity acquired by the particles help in the uniform coating of the sand grains. If this is so, then anything that will cause a discharge of such static electricity should be avoided. Resin and sand must be thoroughly mixed; otherwise, the resultant mold will have a mottled appearance caused by undesirable resin segregation. Figure 2 shows a pair of shell mold halves produced

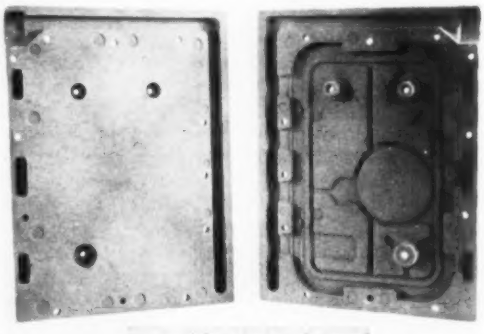


Fig. 2 — A Pair of Shell Mold Halves Produced From the Pattern Plate Shown in Fig. 1

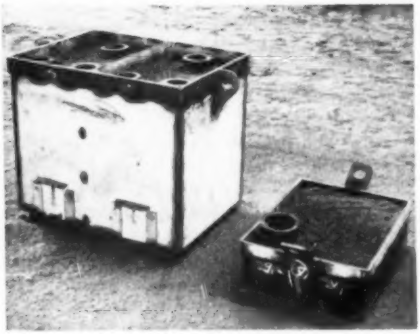


Fig. 3 — The Finished Mold Bedded in the Steel Shot and Ready for Casting

from the master pattern plate in Fig. 1.

Large quantities of resin or of the resin-sand mix should not be stored, since polymerization will progress slowly under varying conditions of humidity and temperature, and a "balling up" may result. The resin might be put in solution before incorporating it with the sand, but sufficient work has not yet been done to justify the idea, and good results have been obtained consistently by the dry-mix method. The mold material is a complete loss after the molten metal has been poured, but this is not a serious drawback.

Another material needed is the releasing agent with which the pattern plate is sprayed to avoid sticking of the investment material. A water emulsion of 2 to 5% silicone concentrate is used. Spraying is done immediately after the pattern plate is removed from the heating oven.

Stripping the plates by hand is not recommended because the pressure cannot be evenly distributed and a twisted mold results. It is important to avoid warping of cope and drag (the mold halves) so that when they are fastened together (either immediately or after storage) the two parts will fit perfectly, thus avoiding fins on the casting. The critical period for warping is the first 60 sec. after the mold is released from the pattern plate.

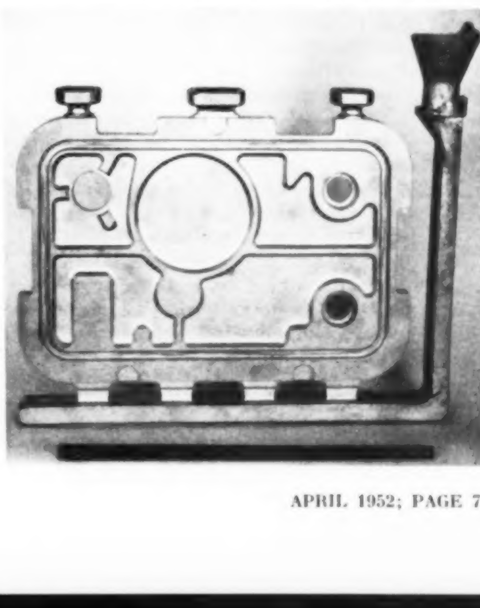
Molds may be closed in a variety of ways. Merely clamping the outside edges with spring wire is a common method. Preferred practice at New York Naval Shipyard is either to bolt the molds together, using Speednuts and an electric torque-controlled nut runner, or to paste them together so as to minimize finning and reduce cleaning-room costs.

The backing material for supporting the shell mold during pouring is simply fine steel shot of about 16 mesh. An iron or steel frame of suitable size and depth to hold the mold and risers is used. The mold (cope and drag suitably bolted together) is laid on a bed of shot and more shot is poured around it to a level slightly below the rim, with the gate protruding (Fig. 3). In some instances a suitable pouring cup of dry sand is joined to the gate. The mold is then ready to pour (Fig. 4). In general, it is preferable to cast molds on edge rather than flat, though both methods can be used.

MOLDING AND CASTING PROCEDURE

A typical procedure, as observed at New York Naval Shipyard, starts with heating the cold pattern plate in an ordinary core oven to, say, 400° F. The temperature depends upon the conditions prevailing, such as kind of resin used and method of mixing. (Plates in a fully mechanized operation may also contain electrical resisters.) The first heating of the cold plate may take up to half an hour; the warm plate of course takes less time. The plate is removed and placed face downward in the container for the investment mixture. The container and plate are

Fig. 4 — A Representative Aluminum Casting Produced From the Mold Shown in Fig. 2 and 3



clamped together and turned over, whereupon the investment material falls on the hot plate. The investment material is softened by the heat of the plate in a matter of seconds. The container and plate are again reversed, and the excess material falls back into the container leaving about 1/8 to 3/16 in. of material of a putty-like consistency adhering to the plate. The coated plate is then carefully placed in the curing oven at approximately 600° F. for about a minute. Time and temperature of curing are carefully predetermined according to the requirements of mixture and ingredients. The finished mold is separated from the plate by suitable release pins incorporated in the pattern plate. It is hard and somewhat brittle, and the color of sulphur, the shade varying with the ingredients. The mold is laid on a flat table while still hot and weighted down with small sand bags for about a minute. It may then be either stored for future use or clamped to the other half (cope and drag), placed in the box backed up with shot, and poured. The total time for making the molds is 2 min. or less.

The final mold is not hygroscopic and may be kept indefinitely. It is also very permeable, which aids the escape of gases. It is sufficiently strong so it will not break easily with ordinary handling precautions.

A slight odor of ammonia while the mold is cooling comes from the decomposition of the resins. The color of the mold is eggshell white before curing; when cured it is a sulphur yellow. After casting, the surface which comes in contact with the molten metal is black but the back of the 3/16-in. section remains yellow.

Pouring temperatures are similar to conventional sand molding temperatures. It should be borne in mind that freedom from shrinkage rather than maximum strength should be the criterion. Frequently a higher temperature will avert shrinkage (probably because of a higher gas content) and is to be preferred to use of a lower temperature.

In the operations observed at the shipyard, 800 castings were made from one pattern with only two defectives. Where optimum pouring temperatures were not adhered to, only 85% were good and 15% defective.

After the mold has been cast the shot must be removed and the casting extricated. In the process some small pieces of the mold get mixed in with the shot. To remove the larger pieces the shot is screened through a 1/4-in. sieve. The small pieces of mold remaining give no trouble. In continuous operation, however, the shot will gradually heat up and provision will have to be made to cool and clean it.

The prime purpose of the backup material is to resist deformation of the mold wall and the hydrostatic head of the metal pressure. The use of shot represents one of the critical material handling problems in the whole process. Such problems as overheating, cleaning fines from the shot, loss due to spillage, and the safety hazards involved when loose shot is on the floor in the pouring area have not been completely or satisfactorily resolved. It is highly likely that this material will eventually be replaced by some other backup material or some other technique. Whatever material is adopted, it should be vibrated during backing up and should have good permeability — an important factor in venting gases.

A first essential of the process is extreme care in making the cast iron pattern plate. It must be well designed if production difficulties are to be avoided. This is a job for a good tool and die shop or a pattern shop used to making accurate metal patterns and effecting quick changes in gating and heading. The fact that the molds can be stored or transported from one plant to another frequently does away with the necessity of making a separate plate for use in each plant.

Cores are made on metal plates and procedure is similar to that for the metal pattern. They are hollow and collapse easily. If preferred, conventional cores may be used.

Once the pattern plate is made, the whole operation can readily be performed by previously untrained workers, girls being especially adept for small work. One large foundry got into production on shell molding in four months.

The future of the process will be associated with the development of automatic or semi-automatic machines. Fortunately, shell molding lends itself readily to mechanization. At least four machines embodying various mechanical methods of handling have already been developed, but it is probable that the machine for general adoption is still to come. Each user or designer is at present working out his own salvation.

By Tom Bishop, Metallurgical Editor, Iron & Coal Trades Review, London, England

European Experiments on Vacuum-Melted Pure Iron

VACUUM MELTING of magnetic alloys and some of the less common metals is now of considerable industrial importance, and occupies the attention of many specialists. Recent European work on this subject has been carried out at the National Physical Laboratory in England[1, 2]* and the research laboratories of N. V. Philips' Gloeilampenfabrieken in Holland,[3]* and other research centers. Iron of reasonably high purity is required in substantial quantities to implement research on the effect of alloying elements on mechanical properties of iron.

A unit for vacuum melting of iron in quantities up to 25 lb. is now in use at the National Physical Laboratory at Teddington, Middlesex. Starting with a selected batch of Swedish iron, the purification procedure was carried out on molten iron in two main stages: *(a)* oxidation of a number of impurities and removal of the products of oxidation, and *(b)* a vacuum treatment for degassing, followed by reduction of oxygen to a low level by dried hydrogen.

The equipment consists of two high-frequency induction furnaces, one a 75-lb. tilting furnace for melting under oxidizing conditions, and the other a 25-lb. furnace for melting under hydrogen. Both furnaces are operated by a 30-kw. motor-generator set, delivering power at a frequency of 5000 cycles. A cutout switch is set at 660 volts and 54 amp. The cooling water operates a relay on each furnace, which switches off the power if the water pressure is insufficient. Below the coil in the Sindanyo base of the 75-lb. furnace is a charge-earthing device, which switches off the power in the event of the melt breaking through the magnesite lining.

The ingot mold used with the 75-lb. prerefining furnace is split; it is made of mild steel, and is 4 in. in internal diameter, 7 in. external diameter and 24 in. long. No dressing is applied to its internal surface, and no trouble is experienced with sticking or "burning on" of the ingot, provided the stream of molten metal is directed onto the existing pool and does not impinge on the side of the mold.

The 25-lb. furnace for final degassification is enclosed in a horizontal cylindrical mild steel tank (see Fig. 1 and 2). The tank is 4 ft. in diameter and 4 ft. 6 in. long; the end is closed by a domed lid, sealed by a tongue and groove with an intervening rubber ring. The tank is evacuated by two rotary pumps through pipe 8 in. in diameter. The furnace can be tilted by a chain and gear arrangement. A separately counterbalanced mold, placed in front of the furnace, is tilted with the furnace when the metal is poured at the end of a run.

The leads to the furnace coil are flexible, and are covered with rubber tubing ¼ in. in wall thickness, to provide insulation and carry the cooling water. The leads enter the tank through an insulating plate, sealed with clamped rubber rings. One of the three openings on top of the tank is closed by a glass plate so the melt can be inspected from above. A second opening is fitted with a Wilson seal, through which a rod is attached to the refractory lid of the furnace. The lid can thus be turned, raised or lowered without leakage of air into the tank. The third opening is fitted with an eccentric sliding valve consisting of two circular plates with off-center holes. The holes can be matched by relative rotation of the plates over their lapped contact faces, the hole in the bottom plate being vertically over the third opening in the tank. A sheathed thermocouple placed in a Wilson seal screwed into the hole in the top plate can be lowered into the melt. The thermocouple sheath can be replaced by a dip-stick to obtain samples

*1. "Production of High-Purity Iron and Iron Alloys on a 25-Lb. Scale", by B. E. Hopkins, G. C. H. Jenkins and H. E. N. Stone. *Journal* of the Iron and Steel Institute, August 1951, p. 377.

2. "Tensile and Impact Properties of Iron and Some Iron Alloys of High Purity", by W. P. Rees, B. E. Hopkins and H. R. Tipler. *Journal* of the Iron and Steel Institute, October 1951, p. 157.

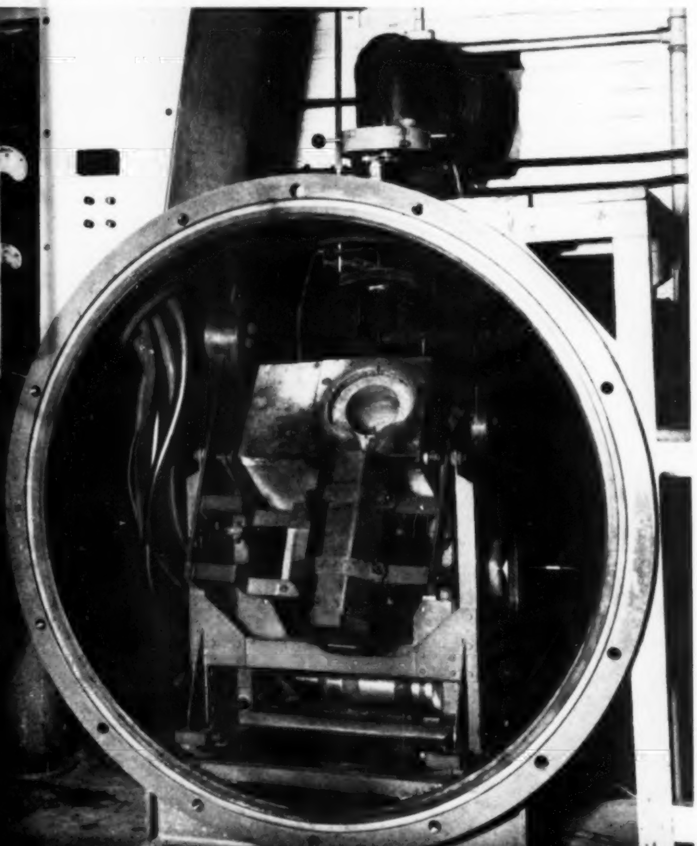
(3) "Ageing of Iron and Steel", by J. D. Fast, *Iron & Coal Trades Review*, April 14, 1950, p. 837.

of the melt at various stages of purification. Additional sightholes are provided in the lid and on one side near the tilting wheel to view the pouring operation.

Figure 3 shows the arrangement of auxiliary equipment for the 25-lb. furnace and the course of the hydrogen flow. Dried hydrogen is drawn into the tank by a small rotary pump, and is passed through a filter and a tube leading through the crucible lid onto the surface of the melt. Water vapor is formed by reaction of hydrogen with the oxygen in the iron, and the moist hydrogen is drawn out of the tank through a furnace containing magnesium turnings at 600° C. (about 1100° F.), to remove nitrogen, and then through a cooler consisting of a cylinder of cold magnesium turnings. Outside the vacuum tank, the hydrogen passes through a water-cooled coil, in which a small amount of the water vapor may condense, and into a large cylindrical drier containing 7 kg. of silica gel. A duplicate train is used in the later stages of a run to dry the hydrogen finally. The capacity of the circulating pump is 120 cu.ft. per hr., and the volume of the furnace enclosure is 60 cu.ft. The melting crucible is made of sintered high-purity alumina and is 4¾ in. in diameter and 9½ in. long; it is packed all around with the same fired magnesite used to line the 75-lb. furnace.

The top inch of the packing is bonded with sodium silicate, so that it sets at room temperature and prevents the loose packing beneath from being drawn out during evacuation of the tank. At the same time it is sufficiently porous so air and any moisture can be removed. The main body of the packing is eventually sintered right through.

Fig. 1 — Apparatus for Melting and Casting a 25-Lb. Charge of Iron in Vacuo Used for Experiments at National Physical Laboratory, England. Furnace is in pouring position. (Crown copyright reserved)



The ingot mold for the 25-lb. furnace is usually made of mild steel, and is octagonal in cross section, the distance across the flats being 2¾ in. internally and 6 in. externally. The mold is approximately 15 in. high, and the top 3 in. is turned out internally to a diameter of 4 in. to take a sillimanite insert, which operates as a hot top. Recently, a tapered mold of similar general design has been used. No dressing is applied to the mold surface.

OXIDIZING MELTS

The base iron is thoroughly cleaned of extraneous matter. Melting a 75-lb. charge takes about 1½ hr. The molten metal is allowed to oxidize for 1 hr., and the iron oxide formed on the surface is continually skimmed off. In early experiments it was found that the carbon content of the oxidized melts was reduced only to about 0.007 to 0.009% (oxygen 0.2 to 0.3%). Much sounder ingots of oxidized iron (increased in density by up to 20%) are obtained by blowing nitrogen or

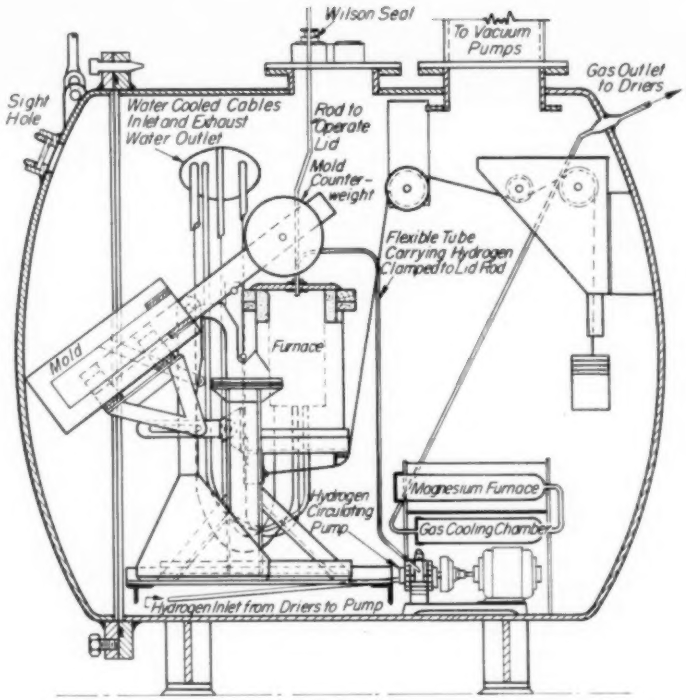


Fig. 2 — Section Through the Steel Tank and Furnace Shown in Fig. 1. (Courtesy *Journal* of the Iron and Steel Institute)

argon onto the melt in the 75-lb. furnace (after the 1-hr. oxidation treatment) for 20 min. to remove carbon monoxide. This procedure has been adopted as standard practice, and it does bring carbon content down to much less than 0.008%; results are not, however, as consistent as the later vacuum treatment in the 25-lb. furnace.

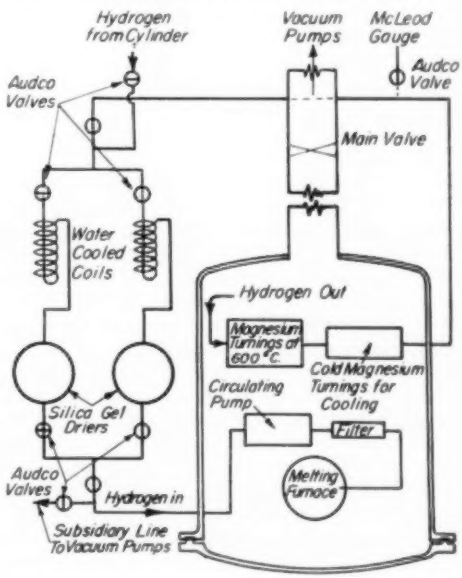
Some of the unsoundness in the oxidized iron ingots, and the evolution of gas in the subsequent vacuum treatment, may be caused by hydrogen formed from the water vapor in the atmosphere. Experience has also shown that the form of the charge influences the carbon content; for example, if the Swedish iron consists of strip or rod instead of heavier sections, the carbon content of the oxidized iron is as low as 0.002%.

The oxidized melts are usually analyzed for carbon, silicon, and sulphur, and run about 0.002 to 0.005% C, 0.002 to 0.003% Si, and 0.004 to 0.006% S. Vacuum fusion analyses of two oxidized irons showed an average of 0.28% oxygen and 0.01% nitrogen. The oxidized iron ingots are machined to remove surface scale, and cut into lengths suitable for melting in the 25-lb. refining furnace.

Reducing Melts

Reducing Melts — The metal for the 25-lb. furnace is first cleaned with carbon tetrachloride and dried before charging in the crucible. After the mold and its support have been clamped in position, the tank is closed and evacuation commenced. When a new crucible is used, it is normal to heat the charge to about 1000° C. (1830° F.) to degas the refractories; after cooling, a pressure of 0.001 mm. of mercury is usually obtained. Such a "heating run" is not conducted if the crucible has been used previously; the time required to reach the limiting pressure then depends on how long the tank has

Fig. 3 — Diagram of Auxiliary Equipment for the 25-Lb. Furnace, Showing Hydrogen Flow



been open after the previous run. If melting was carried out on the previous day, the tank is opened in the morning, and evacuation for the next melt can usually be started in the afternoon; pressures of 0.005 mm. of Hg are obtained in about 1 hr., and 0.001 mm. in about 2 hr. Evacuation is continued for the rest of the day while the silica gel driers are reactivated.

The charge is heated slowly and melts in about $2\frac{1}{2}$ hr. The tank is filled with hydrogen from a cylinder to a pressure of 10 cm. of Hg during this stage, to prevent spurting from gas evolution while the charge is melting. By avoiding spurting, and by increasing the clearance between the solid charge and the crucible wall, initial troubles caused by bridging have been overcome. When the charge is all molten, the hydrogen is removed by opening the main valve connecting the tank with the pumps, and the melt is held for an hour in vacuo while the oxygen content is still high so as to reduce the carbon content. During this period the pressure drops fairly quickly to about 0.05 mm. of Hg, and remains at this level. The pumps are then isolated from the tank, and hydrogen is introduced to a pressure of one atmosphere. The hydrogen circulating pump is started, and hydrogen is blown onto the surface of the melt, passed through the furnace containing magnesium at 600° C. (1100° F.), through the coolers and one of the driers, and then back into the tank. Because of the high conductivity of hydrogen, approximately twice the power is necessary to keep the charge molten as would be required in vacuo.

When reduction is complete, hydrogen circulation is stopped, and the pressure is reduced to 5 cm. of Hg for ½ hr. to control hydrogen evolution from the melt and avoid splashing. The melt is poured at this pressure by simultaneous tilting of the furnace and mold. The ingot is allowed to cool overnight and is removed in the morning. A hydrogen pressure much above 5 cm. of Hg causes a gassy ingot, whereas if the pressure is much lower, there seems to be a greater tendency for the ingot to stick to the mold — presumably because of a less effective adsorbed layer of gas on the inner surface of the mold.

The temperature of the melt is checked periodically with a platinum/platinum-rhodium couple. No sticking to the mold is encountered if the temperature is in the range 1565 to 1585° C. (2850 to 2885° F.) just before pouring, although care still has to be taken that the stream of molten metal does not impinge on the side of the mold at any one spot. This requires a little skill on the part of the operator, and although no trouble is now experienced, it has been suggested that the mold be rotated a few times during pouring, either mechanically or by an electric motor, to avoid prolonged impingement. It is possible that water cooling of the mold would also stop sticking, but this method is not convenient.

When making alloys, the additions are usually packed in iron sheet rolled from a deoxidized ingot, suspended from a cross-piece attached to the tube which holds the lid of the furnace, and lowered into the molten iron after it has been deoxidized. If the additions contain oxygen, the hydrogen treatment must be continued until it has been removed, since the oxides of certain additions are not reduced by hydrogen at the temperatures reached.

Chemical analyses of 35 iron and iron alloy ingots showed the following composition range:

Carbon	0.002 to 0.004%
Silicon	0.002 to 0.003
Manganese	0.004
Sulphur	0.004 to 0.006
Phosphorus	0.001 max.
Nickel	0.005 to 0.007
Chromium	0.001
Copper	0.004 to 0.007
Aluminum	0.001 max.

Aluminum may be higher than 0.001% if the melt has been accidentally overheated, or if the added alloy reduces the alumina crucible wall; some iron-carbon alloys have been made with aluminum up to 0.004%. Adcock has shown that thoria is not attacked by iron-carbon alloys, and if alloys with larger carbon content are desired, it may be necessary to use either thoria or thoria-lined crucibles.

Vacuum fusion analyses of 24 ingots ranged as follows:

Oxygen	0.001 to 0.002% by weight
Nitrogen	0.001 to 0.002
Hydrogen	0.000005 (trace)

These analyses were made on samples that had been hot rolled and normalized from 950° C. (1740° F.), and it will be seen that the hydrogen content is very low, even

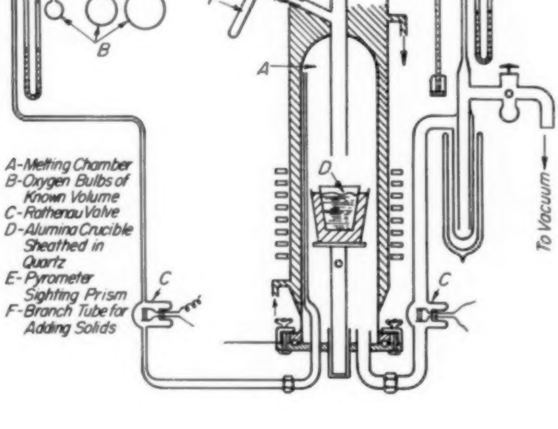
though the ingots were solidified in hydrogen at a pressure of 5 cm. of Hg. The hydrogen content in the cast condition is about 0.00007% by weight.

TESTS ON THE METAL PRODUCED

Physical tests of metal produced in this furnace have been published by Rees, Hopkins and Tipler (see reference 2, page 75). Results show that the purest irons prepared are very ductile at room temperature and at −73° C. (−100° F.) when tested in simple tension, but become brittle on cooling to between −73 and −196° C. (−320° F.). Fracture at −196° C. takes place by cleavage with less than 5% elongation at a stress of about 100,000 psi. — at least double the expected strength of high-purity iron at room temperature. The transition temperature in the Charpy impact test with Izod V-notch occurs at about −15° C. (5° F.). These results refer to material that has been chill cast, rolled, and normalized.

Iron prepared in the same way but containing more than 0.002 to 0.003% oxygen has properties very similar to those of high-purity iron in the ductile condition; however, when the iron is embrittled by cooling to −196° C. the tensile strength is much lower (60,000 to 75,000 psi.) and the fracture is partly intergranular and partly cleavage. The impact transition temperature rises with increasing oxygen content, and the brittle fractures are again partly intergranular.

Fig. 4 — Small-Scale High-Frequency Melting Furnace Used by Dutch Scientists. The apparatus is built entirely of glass. (Courtesy *Iron & Coal Trades Review*)



Effect on Transition Temperature

The limit of oxygen content below which intergranular fractures are not encountered is less in irons of similar purity prepared in a 6-lb. furnace, in which the iron was allowed to solidify slowly in the crucible instead of being chill cast. Intergranular brittleness in an oxygen-containing iron can be enhanced by coarsening the grains through cold work and recrystallization.

The addition of up to 5% manganese to pure iron increases the yield stress and tensile strength; at −196° C. there is also an increase in ductility. No intergranular fractures were observed except in two anomalous alloys that had inferior properties. The tensile test results indicate that manganese raises the cleavage strength of iron more than it raises its yield stress.

Manganese decreases the impact transition temperature, provided that the distorted "α_2 structure" is not present. This structure appears in the normalized alloys containing 3 and 5% manganese, and raises the impact transition temperature, but this effect can be removed by tempering.

Addition of 0.01% carbon to high-purity iron has little effect on the tensile and impact properties of normalized material. Additions up to 0.05% raise the impact transition temperature appreciably, without a large effect on the tensile properties.

Addition of manganese to an iron containing 0.05% carbon progressively lowers the impact transition temperature, which, in an alloy with 2% manganese and 0.05% carbon, is lower than in a simple 2% manganese-iron alloy. Manganese and carbon together also lower the transition temperature in tension. The fractures, when not completely ductile, are cleavage type.

The transition from tough to brittle fracture in impact is usually very sharp in iron and iron-manganese alloys that fail entirely by cleavage in the brittle condition, but it tends to be less sharp when fracture is partly along grain boundaries. The addition of carbon to iron also spreads out the lower end of the transition, but the sharpness is progressively restored by additions of manganese.

Small-Scale Induction Melting

The transition from tough to brittle fracture in tension covers a range of temperature in iron-manganese and iron-carbon-manganese alloys, and it seems likely that this applies also to iron and iron-carbon alloys.

THE PHILIPS APPARATUS

J. D. Fast of the research laboratories of N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, has developed a high-frequency melting apparatus on a smaller scale than that just described for pure iron. By adding fixed quantities of impurities, he has studied aging phenomena in iron and steel. One of the great advantages of an induction furnace is that melting can be carried out in an apparatus made entirely of glass, cooled with circulating water. Thus, the influence of the atmosphere and of gases released from the walls is almost entirely precluded. The apparatus can be evacuated to a pressure of 10^{-8} atmospheres; if desired, it can then be filled with various pure gases. The crucibles were made of pure alumina, rendered impermeable by sintering at temperatures immediately below the melting point of alumina.

Figure 4 is a diagrammatic representation (not drawn to scale) of the apparatus. On the extreme right is the cock used to connect the melting chamber (about $4\frac{1}{2}$ in. inside diameter by $31\frac{1}{2}$ in. high) to the high-vacuum pumps. Cylinders of nitrogen, hydrogen, oxygen, argon, and carbon monoxide are manifolded and arranged so that each can be led through the purification train at will. Oxygen is admitted only in measured quantities, by using bulbs B of known volumes. In the inlet pipe and also in the outlet pipe of the melting chamber are Rathenau valves (C, C). These contain a ribbon of 18-8 chromium-nickel steel, which can be heated by an electric current and can detect traces of oxygen or water vapor in hydrogen, nitrogen or argon by heat tinting.

The alumina crucible D is contained in a larger crucible of clear quartz glass, the space between being filled with coarse pieces of alumina (fragments of discarded crucibles). The temperature of the molten metal can be measured by an optical pyrometer via a prism E.

To produce iron with a known content of impurities, the Dutch scientists start with the purest grade of carbonyl iron (99.9% Fe with impurities almost exclusively carbon, oxygen and nitrogen). The nitrogen can be fully extracted by repeated melting in a vacuum, as can the carbon also, if the metal contains a large excess of oxygen; if the iron is low in oxygen in advance, a known quantity of oxygen can be admitted from the bulbs B. When all carbon has been driven out in the form of carbon monoxide, the excess oxygen is removed by passing a stream of pure hydrogen through chamber A for a prolonged period. The removal of oxygen can be checked at the Rathenau valve C. The hydrogen is removed, in turn, by melting in a high vacuum or in a current of argon.

The pure iron obtained in this way contains no more than 0.001% of carbon, oxygen and nitrogen, and the desired additions are then made. Solids can be added to the melt by turning the branch tube F. Carbon, if desired as an impurity, can also be added in this way in the form of pure graphite. If the substances to be added evaporate rather easily (such as manganese), the addition is made in pure argon instead of a vacuum. The additions blend homogeneously with the iron in a short time as a result of the circulation set up in the bath by electromagnetic forces.

Oxygen and nitrogen are added in the gaseous state. The equilibrium pressure of oxygen over liquid iron containing oxygen is negligibly small, so the oxygen added is entirely absorbed by the iron. The equilibrium pressure of nitrogen over liquid iron containing nitrogen, on the other hand, is great, so that only a relatively small part of the nitrogen added is absorbed. Moreover, when the metal solidifies, it gives off a large part of the absorbed nitrogen. As a consequence, the metal swells and, after solidification, shows large cavities.

To obtain nitrogenous iron without cavities, the procedure is as follows: While the metal is liquid (at about 1600° C. = 2912° F.) the nitrogen pressure is reduced from 1 to 0.2 atmosphere, thereby reducing the equilibrium concentration in the metal from 0.046 to 0.021% nitrogen. The high-frequency current is then switched off and the nitrogen pressure immediately raised again to 1 atmosphere before solidification begins. The metal then solidifies to a compact mass and, after cooling, contains from

0.022 to 0.030% nitrogen. This effect can be understood to a certain extent from the solubility curve for nitrogen in iron. Smaller contents are obtained by choosing lower nitrogen pressures.

QUENCH AGING PHENOMENA

The Dutch apparatus was used to study the role played by oxygen, nitrogen and carbon in the aging of unalloyed iron and of manganese-containing iron. Pure iron was first prepared and known quantities of impurities were added, separately or together.

As shown by Vickers hardness determinations, carbon and nitrogen cause significant quench aging in iron that is otherwise pure. On the other hand, the quench aging of oxygen-containing iron is very slight. The addition of 0.50% Mn has no effect on the action of carbon, but practically suppresses the quench aging of iron containing nitrogen. This remarkable effect of manganese has been confirmed by determinations of damping. In experiments on the damping of torsional oscillations set up in wires, the maximum caused by nitrogen is broadened toward higher temperatures by the addition of 0.50% Mn. This can be explained by assuming that the nitrogen atoms are situated preferentially in the interstitial positions which are in the immediate neighborhood of a manganese atom. The damping observed indicates that the nitrogen atoms can make jumps around the atoms of manganese, but that they find it difficult to leave these atoms. Heating for some dozens of hours at 200° C. (392° F.) is necessary to precipitate a noticeable quantity of nitrogen in the alloys containing manganese.

Oxygen does not cause strain aging in iron. The essential cause of this phenomenon is nitrogen, less than 0.001% sufficing to produce the maximum strain aging. Even at room temperature, this aging takes place with great speed. Strain aging due to carbon only appears at a noticeable speed at elevated temperatures, such as 100° C. (212° F.). This difference between the effects of carbon and nitrogen apparently depends principally on the difference in their solubilities in iron. The time required for strain aging will be controlled mainly by the product of the diffusion coefficient and the solubility of carbon or nitrogen in iron. Manganese has no appreciable effect on the strain aging caused by carbon or nitrogen.

Nominating Committees

In accordance with the Constitution of the American Society for Metals, President John Chipman has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), and two trustees (for two years each). This committee was selected by President Chipman from the list of candidates submitted by the chapters. The personnel is:

Chairman: Gilbert E. Doan (Lehigh Valley Chapter), Head, Department of Metallurgical Engineering, Lehigh University, Bethlehem, Pa.

W. B. Cheney (Fort Wayne Chapter), International Harvester Co., Pontiac St. & Bueter Rd., Fort Wayne, Ind.

J. W. Queen (New Jersey Chapter), Jos. T. Ryerson & Son, Inc., 16th and Rockwell St., Chicago 80, Ill.

Howard E. Boyer (Springfield Chapter), American Bosch Corp., Main St., Springfield 7, Mass.

A. B. Wilder (Pittsburgh Chapter), National Tube Division, U. S. Steel Co., 525 William Penn Place, Pittsburgh 30, Pa.

H. H. Heinisch (Toledo Chapter), National Supply Co., Toledo, Ohio.

R. T. Waddington (Western Ontario Chapter), Dominion Forge & Stamping Co., Ltd., 2480 Seminole St., Walkerville, Ont., Canada.

Gilbert S. Schaller (Puget Sound Chapter), Department of Mechanical Engineering, University of Washington, Seattle 5, Wash.

J. Y. McClure (North Texas Chapter), Manager, Quality Control, Consolidated Vultee Aircraft Corp., Fort Worth, Tex.

Also in accordance with revisions of the constitution adopted in October 1944, a committee for the nomination of secretary (for two years) has also been appointed, consisting of the president of the society as chairman and the six immediate living past presidents. Personnel of this committee is as follows: John Chipman, *Chairman*; Walter E. Jominy, Arthur E. Focke, Harold K. Work, Francis B. Foley, A. L. Boegehold, and Charles H. Herty, Jr.

These two committees will meet during the third full week in the month of May. They will welcome suggestions for candidates in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but individuals of a chapter may suggest to the nominating committee any candidates they would like to have in office. Endorsements may be sent in writing to either chairman or any member of either committee.

By James H. Bechtold, Research Engineer, and Howard Scott, Manager
Metallurgical and Ceramic Dept., Westinghouse Research Laboratories, East Pittsburgh, Pa.*

Properties of Molybdenum Made by Arc Casting and Powder Metallurgy

Molybdenum, with its high melting point, availability and good creep properties, is one of the most promising metals upon which to base new alloys capable of supporting useful loads at temperatures above 1600° F. However, some very serious difficulties must first be surmounted: Molybdenum forms a fusible and highly volatile oxide which rapidly consumes the metal when exposed to air above 1450° F. — a condition that may be improved by alloying.

Pure molybdenum has the reputation of being brittle at room temperature and its alloys would be expected to be even more brittle. Furthermore, it has a relatively low yield strength, which must be improved for engineering uses, and this requires alloying whether oxidation resistance is essential or not. Ductility is therefore a primary concern both in pure molybdenum and in its alloys, and we should know at least the major factors which influence ductility as measured by the tensile test.

Previous experience in other alloy systems and with molybdenum wire had shown that grain size plays a dominant role, ductility being higher the finer the grain. Complete recrystallization to an equiaxed grain was also found to be favorable, although in our early experiments annealing yielded a brittle molybdenum. Extensive studies of its work hardening and recrystallization had disclosed means for rolling and annealing molybdenum so that a uniformly fine-grained and completely recrystallized structure could be obtained consistently. Particularly pertinent at the moment is the possibility of inherent differences in mechanical properties between "powder metallurgy" and "arc-cast" molybdenum.

Molybdenum cannot be melted and cast by conventional means. Nevertheless, chemically prepared powder can be consolidated into ingots suitable for working into usable forms by either powder metallurgy or arc-casting techniques. The ingots produced by the two processes differ in chemical content, microstructure and mechanical properties, as may be seen from Table I. The higher carbon and lower oxygen in the casting result from the addition of carbon as a deoxidizing agent — apparently necessary to produce forgeable ingots. A deoxidizing agent is unnecessary in powder metallurgy molybdenum, since sintering is done in a reducing hydrogen atmosphere.

In the as-cast or as-sintered condition, molybdenum is relatively weak and very brittle but, after suitable working and annealing, ductility at atmospheric conditions is excellent in both the work hardened and the recrystallized conditions. However, there is an abrupt transition from ductile to brittle behavior at temperatures slightly below atmospheric, and service applications will be largely governed by this transition temperature. The transition temperature is also believed to be an exceptionally sensitive criterion of differences in inherent ductility.

METAL PREPARATION

The initial condition of the as-cast ingot is strikingly shown by Fig. 1. In contrast, the ingot derived from powder metallurgy is fine-grained and equiaxed and can be forged and rolled at relatively low temperatures (below the recrystallization temperature). Initial high-temperature forging or rolling breaks down the columnar grain of

*The writers wish to acknowledge the assistance of J. W. Marden, manager of the molybdenum development department, Bloomfield Plant, Westinghouse Electric Corp. Also thanks are due to M. J. Manjoine for making the creep-rupture tests, E. T. Wessel for the tensile tests, and R. L. Anderson for the photomicrographs. The complete paper was presented at the April 1951 meeting of the Electrochemical Society.

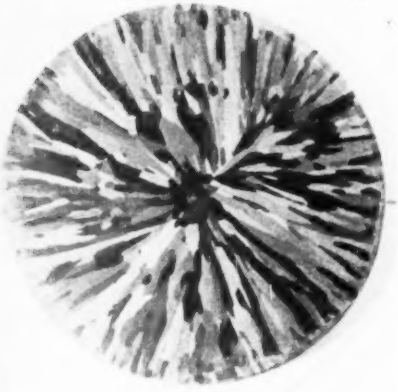


Fig. 1 — Arc-Cast Ingot of Molybdenum. Natural size

the arc-cast (A.C.) ingot and it can then be worked into sheet or bars by the same procedure as the P.M. ingot. The small, equiaxed grain of the latter also facilitates the attainment of a fine final structure, since the only method of controlling the microstructure — which in turn largely controls the mechanical properties — is by work hardening and annealing.

For purposes of the test program to be described, rolling of both A.C. and P.M. bars required reheats between 2060 and 1700° F. (The A.C. was previously hot forged to break down the cast structure.) The time of reheating was regulated to avoid recrystallization so the bars were effectively work hardened with a reduction in area of 91% (from $2\frac{1}{8}$ to $\frac{5}{8}$-in. round). Except for a few molybdenum carbide particles in the arc-cast molybdenum, no nonmetallic inclusions were observed in the microstructure of either material after rolling. Both lots of metal were free from microporosity.

Test specimens were machined from the $\frac{5}{8}$-in. bars in the as-rolled condition and then annealed for 30 min. at 2100° F. in dry hydrogen. This produced the completely recrystallized and equiaxed grain structures shown in Fig. 2 and 3. Tensile and creep-rupture specimens had plain shoul-

Table 1 — Description of Material Tested

Consolidation Process	Arc-Cast	Powder Metallurgy
Lot identification	A.C.	P.M.
Source	Climax Molybdenum	Westinghouse
Impurities	0.031% carbon 0.0002% oxygen 0.0056% nitrogen Spectrographic traces of Fe, Si, Cu, Mg	0.004% carbon 0.006% oxygen 0.0041% nitrogen Spectrographic traces of Fe, Si, Cu, Mg
Initial condition	$2\frac{1}{8}$-in. round billet as hot worked. Grain size No. 4.7	$2\frac{1}{8}$-in. round ingot as sintered. Grain size No. 9.4
Rolling procedure	Rolled to $\frac{5}{8}$-in. round at 1900 to 1700° F.	Rolled to $\frac{5}{8}$-in. round at 1900 to 1700° F.
Microstructure as annealed 30 min. at 2100° F. and furnace cooled	Grain size No. 7.3 1200 grains per sq.mm. See Fig. 2	Grain size No. 7.8 1650 grains per sq.mm. See Fig. 3

Fig. 2 — Worked and Recrystallized Arc-Cast Molybdenum. Average grain size A.S.T.M. No. 7.3. Magnification 100 ×

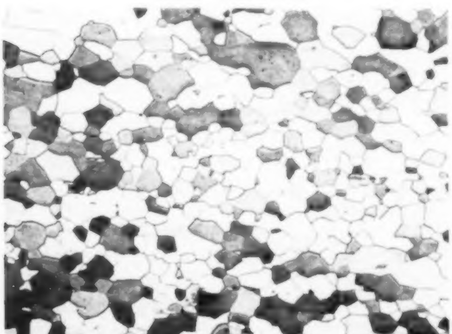
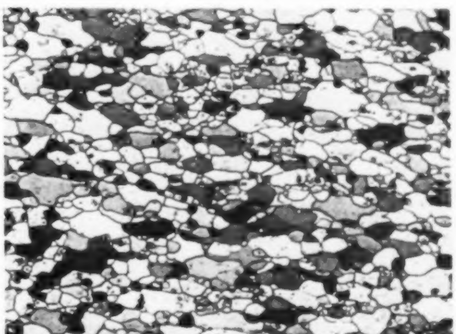


Fig. 3 — Worked and Recrystallized Powder Metallurgy Molybdenum. Average grain size A.S.T.M. No. 7.8. Magnification 100 ×



Tensile Properties of Molybdenum

ders (see Fig. 6); reduced sections were 0.252 in. diameter, gage lengths 1½ and 2 in. respectively.

Tensile specimens were pulled at a slow, approximately constant strain rate of 100% per hr., slightly slower than that ordinarily used for the "static" tensile test. The testing machine is somewhat special and has been described elsewhere; total deformation between crossheads is autographically recorded.

TENSILE TESTS

Stress-strain curves at several temperatures are replotted in Fig. 4. There is an abrupt change in the tensile properties at temperatures slightly below atmospheric. True stress at fracture and reduction in area (both uniformly distributed and at the neck) are plotted against test temperature in Fig. 5. Reduction in area values above 100° C. (212° F.) are probably low because of longitudinal splitting in the neck prior to transverse fracture. For this reason, the true stress at fracture is also somewhat uncertain. However, these conditions did not exist in the temperature range of most interest, namely, the transition from ductile to brittle fracture and below.

Both materials had pronounced upper and lower yield points, a characteristic commonly observed in metals with the body-centered cubic structure. In molybdenum this is also believed to be related to the nitrogen content. (It may be remarked, in passing, that the upper and lower yield points in annealed mild steel have also been correlated with nitrogen or carbon, or both.)

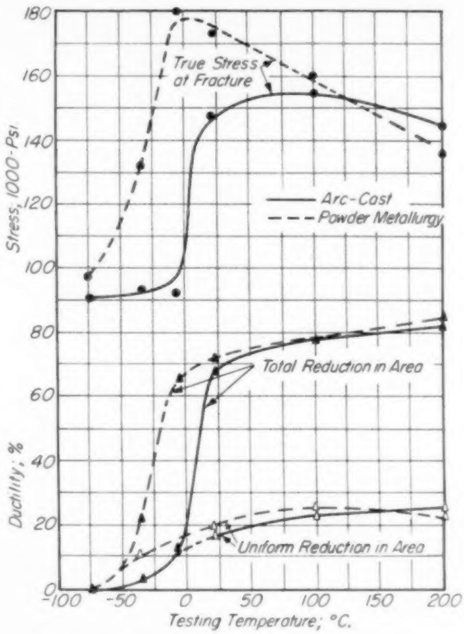
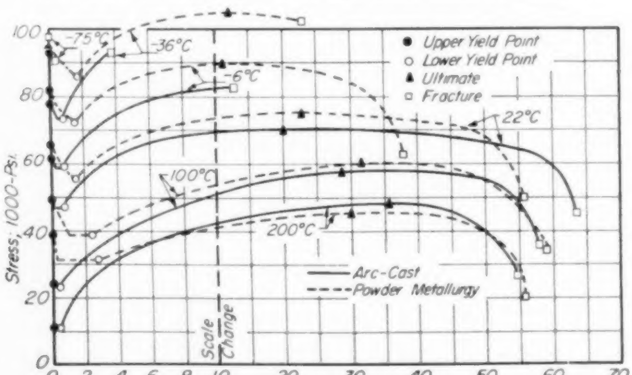


Fig. 5 — True Stress at Fracture and Reduction in Area Plotted Against Test Temperature

The curves for total reduction in area best illustrate the abrupt transition from ductile to brittle behavior. If, for purpose of comparison, a "transition temperature" is defined as the point where the total reduction in area attains a value halfway between maximum and minimum values, it is +41 and −12° F. (+5 and −25° C.) for the A.C. and P.M. types of molybdenum respectively.

Above this transition zone both types have excellent ductility; below this zone both are completely brittle. The differences do not indicate any significant superiority for the powder

Fig. 4 — Stress-Strain Curves of Molybdenum at Several Temperatures Show an Abrupt Change Slightly Below Room Temperature

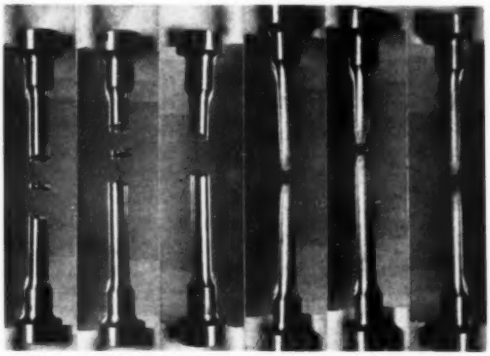


metallurgy product but can probably be attributed to a smaller grain size and normal variation, sample to sample.

The transition is also apparent from the fractured test specimens in Fig. 6. Double fractures at −101 and −33° F. (−74 and −36° C.) were probably caused by elastic shock waves; the P.M. specimens also had double fractures in this range.

Types of fracture were similar in the two materials. Below the transition temperature, fracture occurred through the grains, probably on the (100) crystallographic planes, with no measurable plastic deformation. The fractured surface was bright

Fig. 6 — Fractured Tensile Specimens of Arc-Cast Molybdenum Tested at Various Temperatures



−74 °C. −36° C. −7° C. 20° C. 100° C. 200° C.

— typical of the fracture observed in most brittle metals that fail by cleavage — and approximately normal to the direction of loading. Microscopic examination showed well-defined cleavage facets which had numerous strain markings, even in the specimens for which no measurable plastic deformation was observed.

Specimens tested in the transition range also failed with a bright, cleavage type of fracture, normal to the direction of loading. The cleavage facets had numerous strain markings and were rounded and somewhat distorted.

Specimens tested above the transition temperature had a dull, fibrous type of fracture, similar to the so-called ductile-shear fracture in mild steel. Numerous longitudinal splits were observed in the necked-down region, and, because of the large amount of plastic deformation, microscopic examination was difficult and inconclusive.

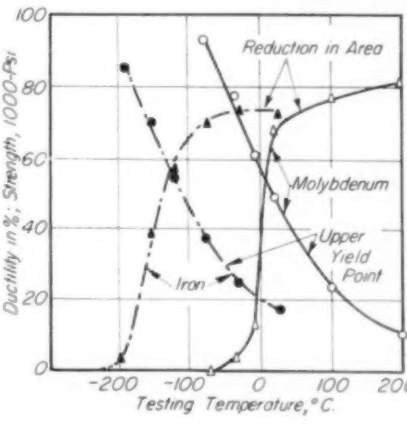
*Reported by F. F. Witman and F. A. Stepanoff, *Journal of Technical Physics*, U.S.S.R., Vol. 9, 1939, p. 1070; by H. E. Davis, E. R. Parker and A. Boodberg, *Proceedings*, American Society for Testing Materials, Vol. 47, 1947, p. 483; and by J. M. Hodge, R. D. Manning and H. M. Reichhold, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 183, 1949, p. 233.

CAUSE OF TRANSITION IN DUCTILITY

An abrupt transition from ductile to brittle behavior is not a unique characteristic of molybdenum. Iron and ferritic iron-base alloys show a similar behavior at a much lower temperature. The striking similarity — except for a difference in temperature — is illustrated in Fig. 7. Tungsten, tantalum, chromium and other metals that have a body-centered cubic structure will undoubtedly exhibit this behavior when tested under comparable conditions. It has not been observed in metals and alloys that have a face-centered cubic structure such as copper or austenitic steels.

The reasons for an abrupt transition have not been determined; however, many of the factors which affect its temperature have been identified. Work at Westinghouse Research Laboratories on molybdenum, plus numerous tests on steel,* show that increased strain rate, stress conditions that restrain the flow of the metal, or an increase in the grain size will raise the transition temperature. Strain hardening induced by

Fig. 7 — Tensile Properties of Molybdenum and Annealed Ingot Iron as a Function of Testing Temperature. The iron contained 0.02% C, 0.058% O_2, 0.002% N_2, 0.005% P, and 0.018% S; grain size was A.S.T.M. No. 2 to 3. (According to G. W. Geil and N. L. Carwile)

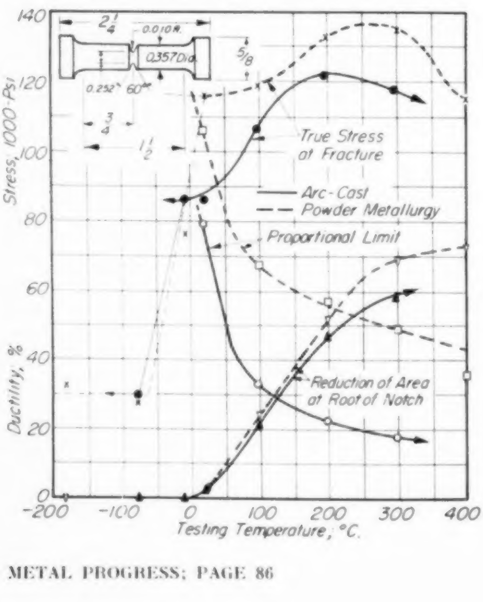


rolling, forging or drawing lowers the transition temperature in the direction of metal flow — or, at least, tends to retain some ductility below the transition temperature. However, the ductility normal to the direction of flow is reduced by strain hardening. Nonmetallic impurities, such as carbon, oxygen and nitrogen that form interstitial solid solutions, probably raise the transition temperature. It would be interesting to know if body-centered cubic metals completely free of these impurities would behave in this manner.

The effect of one of the factors on the transition temperature can be illustrated by tests on notched tensile specimens. The notch inhibits plastic flow and concentrates local stress at the root. The specimen sketched in Fig. 8 has a sharp V-notch with a calculated elastic stress concentration factor of 3.1 at the root. Reduction in area, proportional limit and true stress at fracture for such specimens are also plotted. Comparing this figure with Fig. 5, we see that the transition from ductile to brittle behavior is 250 to 300° F. (120 to 150° C.) higher than for the standard tensile specimen.

Probably of greater importance than the higher transition temperature is the very low stress at fracture below the transition temperature. As shown in Fig. 8, these stresses are the average over the reduced area under the notch; however, because of the stress concentrations, a stress several times this average can occur. Above and in the transition range sufficient plastic deformation occurs at the root of the notch to relieve these concentrations, but below the transition temperature molybdenum behaves in an almost elastic manner and the stress concentrations are not relieved. This results in a high local stress; a crack starts and propagates at a very low *average* stress. If this average true stress at fracture is multiplied by 3.1, the axial stress concentration factor, the actual stress at the root of the notch at fracture is found to be approximately the same as that for the standard tensile specimens when tested at the same low temperature. These results illustrate the importance of avoiding sharp changes in contour in molybdenum parts that must support loads — especially dynamic loads — at temperatures close to atmospheric. The notched specimens failed with the same types of fractures as those observed in the standard tensile specimens.

Fig. 8 Notched-Bar Tensile Properties of Arc-Cast and Powder Metallurgy Molybdenum



It should be emphasized that our specimens were tested at slow strain rates. Accordingly, extreme caution must be used in applying room-temperature tensile data for predicting *service* behavior close to room temperature. A part fabricated from molybdenum may act in an entirely different manner if the loading conditions, such as stress system, strain rate and size, depart materially from those of the tensile test.

CREEP-RUPTURE TESTS

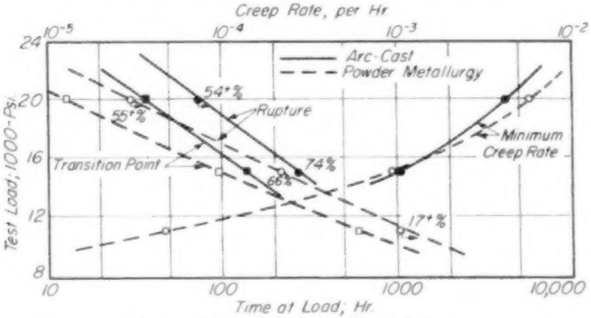
Creep tests have previously been made on molybdenum as reported by Scott in *Metal Progress*, Vol. 58, October 1950, p. 503, but his material was somewhat coarser grained and perhaps not as reproducible as that used in these later tests. On that account, it was felt that tests at a single temperature, 1600° F. (871° C.), would suffice for a comparison. The creep testing machine described by Manjoine in *Transactions*, American Society of Mechanical Engineers, Vol. 67, 1945, p. 111, was used with an atmosphere of hydrogen.

Data for our A.C. and P.M. molybdenum at 1600° F. are plotted in Fig. 9. Both have similar creep-rupture properties. The arc-cast variety had a slightly longer rupture life

and slower creep rate at 20,000 psi. but not at 15,000 psi., so it is doubtful that there is any significant difference. Plastic strain at rupture is also recorded; it shows the high degree of ductility of molybdenum at 1600° F.

In Fig. 10 the 100-hr. rupture strengths of molybdenum, iron, cobalt and two of the better so-called superalloys are compared. The rupture strength for molybdenum at 1600° F. was obtained from Fig. 9, and at higher temperatures from tests reported by Scott (in the October 1950 *Metal Progress* article) on completely recrystallized but relatively coarse-grained swaged molybdenum bars. Iron and commercial cobalt, both in the annealed condition, were tested by J. K.

Fig. 9 — Creep-Rupture Data at 1600° F. in Hydrogen. The figures represent plastic strain at rupture



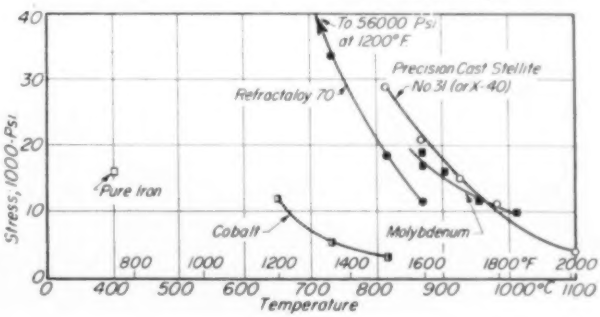
Figures Represent Plastic Strain at Rupture

Stanley in this laboratory. The iron contained 0.012% carbon, 0.04 to 0.06% oxygen, and less than 0.01% total metallic impurities; the commercial cobalt, 0.011% C, 0.0043% O_2, 0.45% Ni, 0.07% Mn, and 0.12% Si. Refractaloy 70 is a wrought material, a precipitation hardened, nickel-cobalt alloy (Co 30, Ni 20, Cr 20, Fe 15, Mo 8, W 4, C 0.05), and Haynes Stellite No. 31 (or X 40) is a precision-cast cobalt-base alloy (Co 55, Cr 25, Ni 10, W 7.5, C 0.50).

When compared on the basis of equivalent 100-hr. rupture strengths, Fig. 10 shows that molybdenum has about the same rupture strength as iron does when 932° F. cooler, or cobalt does 572° F. cooler. The creep-rupture strength of pure nickel has not been reported, but it would probably be intermediate between iron and cobalt. The rupture strength of iron, cobalt or nickel can be increased greatly by proper alloying (see the curves for Refractaloy 70 and Haynes Stellite No. 31), but even then their rupture strength above 1650° F. is no better than that of *pure* molybdenum. A considerable improvement in its creep properties should be possible by proper alloying. In fact, a 100-hr. rupture strength of over 30,000 psi. at 1600° F. has been obtained in pure molybdenum simply by work hardening, but such improvement is not feasible above the recrystallization temperature, 1650 to 1750° F.

Figure 10 does not mean that pure molybdenum would be as good a material as the superalloys for normal high-temperature applications, especially where oxidation resistance or dimensional stability is required. Hot molybdenum oxidizes very rapidly in air or other oxidizing atmospheres. Even in a reducing atmosphere, pure molybdenum creeps very rapidly and a relatively large amount during the initial creep stage. This prohibits its use where dimensional stability is important. This high initial creep can be partially eliminated by work hardening, but again it would eventually recrystallize above 1650° F. with subsequent rapid creep. The excellent ductility indicates that it should be possible

Fig. 10 — 100-Hr. Rupture Strengths of Molybdenum, Iron, Cobalt and Two of the Superalloys



to add a considerable amount of alloy, thereby improving first-stage as well as over-all creep strength, and still retain satisfactory high-temperature ductility.

SUMMARY AND CONCLUSIONS

Billets of arc-cast and powder metallurgy molybdenum were prepared in the fully annealed and completely recrystallized condition. Tests showed little difference between A.C. and P.M. varieties in tensile properties over a range of temperatures above and below atmospheric, or in creep strength at 1600° F.

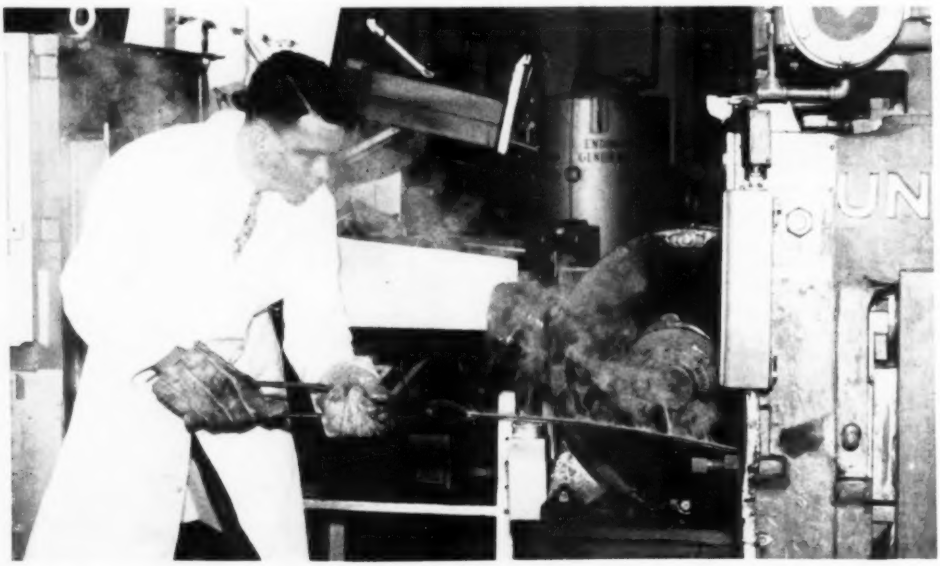
The cold brittleness of molybdenum was found to be associated with a well-defined transition from ductile to brittle fracture on a tensile test at a temperature only slightly below atmospheric. The brittle condition is characterized by a cleavage-type fracture such as occurs in iron near liquid air temperatures. Above the transition temperature, ductility is quite high.

Influence of stress distribution on the transition temperature was studied, using a notched tensile specimen with a theoretical stress concentration factor of 3.1. This condition raised the transition temperature to 257° F. (125° C.). The occurrence of this transition near room temperature and the pronounced influence of many factors call for meticulous control of fabrication for maximum cold ductility. Lowering of the transition temperature by alloying may be possible, as it is in iron, by the addition of a correct percentage of nickel.

The creep and rupture strength of molybdenum in the fine-grained annealed condition is high relative to other pure metals used for high-temperature alloys, and is superior to the best of the conventional alloys above 1650° F. Undoubtedly this property can be considerably improved by alloying and possibly some degree of atmospheric oxidation resistance could be conferred as well, with the retention of a reasonable amount of hot ductility.

None of the tests showed any significant difference between A.C. and P.M. molybdenum in a comparable structural condition, although there are considerable differences in their hot working characteristics. Differences in carbon, nitrogen and oxygen content may be responsible for the upper and lower yield points observed in both materials. Material of extremely high purity will have to be prepared and tested to answer the questions raised by these observations.

Fig. 11 — A Hot Bar of Molybdenum-Base Material Being Rolled Into Strip in the Westinghouse Research Rolling Mill. The smoke is molybdenum trioxide



By W. H. Holcroft, Executive Vice-President and Technical Director
and D. J. Schwalm, Metallurgical Engineer, Holcroft & Co., Detroit

Influence of Temperature, Gas Composition and Flow on Carbo-Nitrided Cases

An article in the December 1950 issue of *Metal Progress* dealt with the generalities of carbo-nitriding, such as background, scope, and classification. It ventured a rule-of-thumb classification of the many applications of the process, wherein Class I included a large majority of the commercial uses. In this class the object is to produce a light case by heating at medium temperatures (1450 to 1650° F.) in a carburizing gas carrying a low ammonia addition. Class II comprises carbo-nitriding, at low temperatures (1200 to 1450° F.), parts of thin metal which might be expected to distort beyond acceptable limits in a normal hardening quench. Class III comprises duplex treatments to give hard cases and annealed cores in the part.

This article will attempt to substantiate some of the theories of the process by reporting certain laboratory and production experiences. It will deal with specific aspects of the common Class I process, such as the effect of ammonia on case properties; the effect of rate of flow; the effect of CO-CO_2 equilibrium; and the effect of temperatures above 1450° F.

As was pointed out in the first article, contradictory results in some of the articles published about the process are probably due to uncontrolled variations in the composition of the gas actually in contact with the work and uncertainties in the amount of nitrogen absorbed by the work.

To perform the type of confirmatory experiments we had in mind, it was first necessary to be able to measure the very small percentages of undissociated ammonia leaving the heating chamber, and determine the percentages of nitrogen added to the specimens. The first of these problems was solved by the perfection of a rapid and accurate analytical method of ammonia determination in effluent gases.

The other problem (nitrogen analysis of the metal) was somewhat more difficult. In our early laboratory work we took turnings from carbo-nitrided pieces and sent portions of a single sample to our own chemical laboratory as well as other cooperating laboratories. We were unable to get close checks between laboratories, so we finally discarded the direct chemical analysis for determining nitrogen. In most of our early work, therefore, results of various heat treatments were compared microscopically.

Figure 1 shows the results of an early group of four tests run in a laboratory furnace at 1510° F. using generator gas and varying amounts of ammonia and propane. They are interesting from the standpoint of hardness and the microstructure of the cases produced. The samples used for microscopic examination were light sections of S.A.E. 1020 steel. They were quenched in oil after 2½ hr. at temperature in the gas of the composition indicated in the caption below the micros. In all tests the total volume of gases passing through the furnace was kept constant at about 24 cu.ft. per hr.

File Hard Cases Produced

The photomicrographs of the cases at 750× indicate that increasing percentages of both ammonia and propane influence the amount of austenite retained in the case and also the amount of "white layer" produced on the surface. All of the test pieces were file hard; the Rockwell hardness seemed to vary inversely with the amount of untransformed austenite.

In the first test, 1-A, the atmosphere consisted of generator gas and 2½% propane. For the second run, 1-B, the propane was omitted and the atmosphere fed to the work

chamber contained generator gas and 1¼% ammonia. Both cases so produced are martensitic, but a small amount of austenite has been retained in sample 1-B; at a temperature of 1510° F., carbon monoxide supplied in sufficient quantity in the generator gas is considered to have carburizing activity. For 1-C, propane was again omitted and the ammonia was increased to 2½% of the input gas; its microstructure shows a decided increase in the amount of austenite which has been retained, and also a white layer has begun to form on the very surface. For the fourth test, 1-D, the ammonia was kept at 2½% and a like quantity of propane was added with the generator gas. The microstructure shows approximately the same amount of austenite as 1-C, with a definite increase in the depth of white layer; this seems to indicate that carbon is a constituent of this component at the surface as well as nitrogen. In all runs the time, temperature and quenching rate were the same.

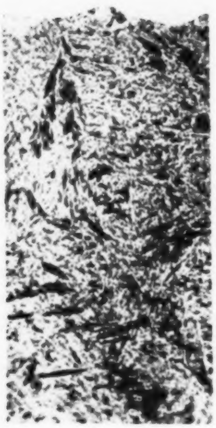
EFFECT OF VARIABLE AMMONIA

Subsequently, several series of laboratory tests were made to determine the effect wide variations in ammonia additions to the atmosphere would have on the nitrogen absorbed by the steel. A small laboratory furnace was used, having a retort 6 in. diameter by 6 in. long. Samples were low-carbon (0.07%) shim stock, 0.050 in. thick, ½ in. wide and 1½ in. long, which weighed approximately 5 g. Samples were accurately weighed before and after carbo-nitriding and the gain in weight recorded. The entire sample was analyzed for carbon and the difference between calculated weight gained by carbon and total weight gained was assumed to be the weight of nitrogen added to the steel. This could then be figured back to percentage of nitrogen.

In any one series of tests the temperature was maintained constant; time in furnace was also constant; the carrier gas and the natural gas flow was constant; the ammonia addition was the only variable. The carrier gas flow was maintained at either 32 or 45 cu.ft. per hr. When natural gas was used it was at 1 cu.ft. per hr. Continuous Orsat analysis and ammonia determinations of inlet and outlet gases were made. The ammonia in the inlet gas was varied from approximately 3 to 33% in the different tests.

The results of one series are shown in Fig. 2. These tests were all run at 1550° F.; time in the furnace was 1 hr.; generator gas flow was 32 cu.ft. per hr.; natural gas addi-

Fig. 1 — S.A.E. 1020 Heated 2.5 Hr. at 1510° F. and Oil Quenched. 750 ×. Gas additions shown are to generator gas. Hardness numbers are converted from 15 N readings



Test 1-A
2.5% C_3H_8
C-56

Test 1-B
1.25% NH_3
C-60

Test 1-C
2.5% NH_3
C-56

Test 1-D
2.5% C_3H_8 + 2.5% NH_3
C-47

tion was 1 cu.ft. per hr. From the data obtained it can be seen that as the percentage of ammonia in the inlet gas was increased, *(a)* the amount of nitrogen added to the steel increased, *(b)* the amount of carbon added decreased slightly, and *(c)* the Rockwell hardness progressively decreased. This is a point worthy of note because it has been our contention for a number of years that many industrial installations use unnecessarily large amounts of ammonia in their carbo-nitriding atmospheres. If ammonia is added solely to increase the nitriding potential of the atmosphere and not to counteract poor carrier gas conditions, it not only decreases hardness (and wear resistance) but also increases production costs.

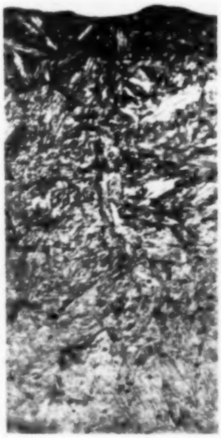
The carrier gas for these tests conformed to American Gas Assoc.'s Type 302.* In

by Orsat analysis. Carbon would be absorbed by the hot metal at a slower rate through either dilution of CO by N_2 (reducing the number of contacts between metal and carburizing gas) or through the presence of small amounts of CO_2 (which shift the equilibrium of the reaction $3\,Fe + 2\,CO \rightleftharpoons Fe_3C + CO_2$). When these runs were repeated using a generator gas containing a higher percentage of carbon monoxide, the amount of carbon absorbed returned to the same level as in the lower ammonia runs, 2-A and 2-B.

While carbon and nitrogen in this series are reported as per cent, this is the per cent of weight gained by the sample, and is not intended as concentration of either element

Fig. 2 — First Series of Tests on 0.07% C Shim Stock, Oil Quenched After 1 Hr. at 1550° F. (These and remaining micrographs in this article are at 500 ×.) Atmosphere consisted of 32 cu.ft. per hr. of generator gas, 1 cu.ft. per hr. of raw natural gas (principally methane), and a variable amount of ammonia as indicated. Figures for carbon and nitrogen are computed from weight gains and represent average for whole thickness

Test 2-A
3% NH_3
C-62
0.22% C
0.10% N



Test 2-B
9% NH_3
C-60
0.22% C
0.16% N

Test 2-C
23% NH_3
C-56
0.21% C
0.22% N

Test 2-D
33% NH_3
C-52
0.18% C
0.29% N

Tests 2-C and 2-D, wherein a large volume of ammonia was added, the carbon monoxide in the furnace gas was reduced by dilution to about 10%. It is believed that the slightly lower carbon addition in these samples than in 2-A and 2-B was caused by a changed $(CO)^2/CO_2$ ratio undetectable

*This is an endothermic base, completely reacted by 2½ times as much air as 1000-B.t.u. natural gas, and quickly cooled to eliminate sooting of CO. Its representative analysis is 39.8% N_2, 20.7% CO, 38.7% H_2, 0.8% CH_4. It is combustible, toxic and very reducing in nature when in contact with iron oxides at heat treating temperatures. See *Metal Progress* Data Sheet for August 1947, p. 256-B.

Effect of Temperature

in the case. Microscopic examination of the pieces showed total penetration of approximately 0.015 in. to be quite uniform in all the samples.

In Fig. 2, a variation in the depth of hardened case can be noted. This may be due to slight differences in quenching rates caused by the difficulty in moving such a small piece of steel from the work chamber through air to the oil quench, several feet away, without slight variations in the temperature of the samples. This difficulty is not encountered in production, where proper design of equipment insures uniform processing of all pieces. Furnace cooled samples, in which quenching was not a factor, showed the total penetration to be quite uniform for all four gas concentrations. In these tests the quenched and furnace cooled samples were processed simultaneously for each gas concentration. The oil quenched samples were used for microscopic examination, while the furnace cooled samples were used for carbon and nitrogen determinations, as well as for microscopic examination.

Figure 3 shows the effect of temperature on case structure. Furnace conditions were the same as 2-D with the exception that each sample was run at a different temperature, and 3-A at 1450° F. was run with a lower percentage of ammonia in the inlet. As would be expected, increasing the temperature of carbo-nitriding has the following effects: *(a)* The amount of nitrogen absorbed decreases, because of the lower nitriding potential of the atmosphere; *(b)* the compound layer formed at the lower temperatures disappears, because of higher diffusion rates and the decrease in nitriding potential of the atmosphere; *(c)* the amount of carbon absorbed increases, because of higher diffusion rates; *(d)* the Rockwell hardness increases, because of combined increase of absorbed carbon and decrease of absorbed nitrogen; *(e)* the case depth increases, because of the higher diffusion rates.

Figure 4 shows the effect of rate of flow of the furnace

Fig. 3 — Effect of Temperature on Case Structure of Sample 2-D. (Sample 3-B is the same as 2-D.) Figures for carbon and nitrogen are grams of element added to the entire sample (0.050 x 0.50 x 1.50 in.)

Test 3-A
1450° F.
23% NH_3
C-48
0.0065 g. C
0.0206 g. N

Test 3-B
1550° F.
33% NH_3
C-52
0.0085 g. C
0.9144 g. N

Test 3-C
1700° F.
33% NH_3
C-64
0.0093 g. C
0.0131 g. N

atmosphere. These samples were run under the same conditions otherwise as the two previous series, with the exception that no natural gas was added to the atmosphere and changes were made in the composition of the carrier gas. The CO was raised from 20% to 35% by adding carbon dioxide to the mixture of air and natural gas reacted in the standard Type 302 generator. This was done to increase the carburizing power of the generator gas and to show the importance of carbon monoxide as a carburizing medium. A comparison of the amount of carbon absorbed in this series and Test 3-B (Fig. 3) seems to confirm this belief. The amount of nitrogen absorbed in these samples is less than in the tests shown in Fig. 3 and this is believed to result from the disturbance of the equilibrium between NH_3, H_2 and N_2. The carbon dioxide going into the gas generator reduces the percentage of hydrogen in the carrier gas and, therefore, reduces the stability of the ammonia — it dissociated enough to tend to replace the missing hydrogen.

As shown in Fig. 4, increasing the flow of the furnace atmosphere above the minimum necessary for consistently good results has little or no effect on the amount of carbon added. It does, however, slightly increase the amount of nitrogen absorbed by the hot steel.

In summarizing, it can be concluded that increasing the temperature of carbo-nitriding causes:

1. A decrease in the amount of nitrogen absorbed.

2. An increase in the amount of carbon absorbed.

3. A decrease and eventual disappearance of a white layer.

4. An increase in the Rockwell hardness.

An increase in the percentage of ammonia in the furnace atmosphere for a given temperature causes:

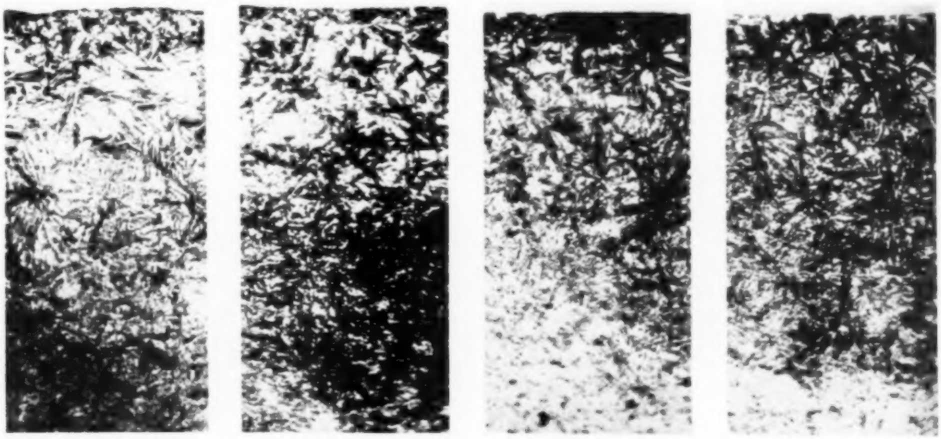
1. An increase in the percentage of nitrogen absorbed.

2. A decrease in the amount of carbon absorbed.

3. A decrease in the Rockwell hardness.

An increase in the rate of flow of the furnace atmosphere within reasonable limits has little effect other than slightly increasing the amount of nitrogen absorbed.

Fig. 4 — Excessive Rate of Flow of Atmosphere Has no Effect on Carburizing Action, and Slightly Reduces the Nitriding Action. Tests 4-A and 4-B are one pair; 4-C and 4-D are another. Specimens oil quenched after 1 hr. at 1550° F.



Test 4-A	Test 4-B	Test 4-C	Test 4-D
23% NH_3 in inlet		9% NH_3 in inlet	
45 cu.ft.	32 cu.ft.	45 cu.ft.	32 cu.ft.
C-60	C-62	C-61	C-65
0.0122 g. C	0.0124 g. C	0.0133 g. C	0.0131 g. C
0.0088 g. N	0.0080 g. N	0.0071 g. N	0.0066 g. N

Correspondence

Refining Steel With Oxygen

KAPFENBERG, AUSTRIA

A symposium on the refining of steel with oxygen was held in December 1951 in Leoben, Austria, which may be of especial interest to American metallurgists, since the method will be used for producing nearly one quarter of all Austrian steel this year. It is especially suitable for the blast furnace iron available in this country, whose composition is 3.7 to 4.3% C, 0.2 to 1.0% Si, 1.6 to 3.0% Mn, 0.08 to 0.20% P, and 0.08% S max. Molten iron is being blown to steel without any external source of heat in the following manner:

Basic converters of 5 to 15 tons capacity, of the side-blown design, while in the upright position receive a proper charge of molten pig iron. (As a matter of fact, the original experiments were made in a hot-metal ladle at the Linz works of the Vereinigte Österreichische Eisen und Stahlwerke.) A vertical, water-cooled pipe about 1 in. diameter is lowered into the vessel through the mouth until its end just clears the top of the bath, and oxygen is blown through for 18 to 20 min. Oxygen consumption is 1950 to 2000 cu.ft. per ton of finished steel. About 20% scrap is needed to keep the temperatures within limits. Nitrogen in the finished steel is 0.006 to 0.008% when the oxygen carries no more than 2% N, but increases to 0.016% when a crude 75:25 O_2:N_2 mixture is blown on the bath. Phosphorus is brought down to 0.03% in the 15-ton vessel.

It was pointed out by K. Rösner that costs are lower than the conventional pig-and-ore process in the openhearth, particularly if the scrap does not need to be carefully sized before charging. Other commentators testified that the quality of such steels was equal to or better than openhearth steel as to its hot and cold working properties, stability (nonaging) and weldability.

There are clearly several advantages in this system. The separation of the oxygen supply from the converter means that difficulties in preserving the tuyeres from damage during the filling and emptying of the vessel are entirely avoided as well as difficulties with pipe connections and with water coolers when the vessel tilts. But principally there is the fact that, during conversion, the point of maximum heat development (that is, the point where the oxygen stream impinges on the metal) is removed as far as possible from the walls of the vessel. Thus at one stroke all the old trouble with excessive tuyere consumption and rapid failure of the converter lining is avoided.

M. Hauttmann discussed the mechanism of the process, saying that direct oxidation occurs mainly and very rapidly at the region near the end of the oxygen pipe (creating local temperatures so high that oxides of iron and manganese actually volatilize). This region of rapid reaction may be regarded as a hemisphere with the oxygen pipe at its center; the metal in this sphere is stirred violently and it continuously works out into the surrounding metal, being replaced with other metal containing more of the oxidizable elements carbon, silicon and manganese. Metal leaving the hot center carries with it considerable oxygen which reacts with the bath some distance away.

FRANZ RAPATZ
Technical Director of Steel Works
Gebruder Böhler & Co.

High Temperature Scale Resistance

PARIS, FRANCE

Getting good chemical resistance at high temperatures out of metals and alloys requires application of some general principles that we pointed out long ago and which we can review summarily here. To increase oxidation resistance of a metal, a solute element must be added which in itself oxidizes more readily than the solvent metal but whose oxide is more refractory than the oxide of the solvent — that is, the oxide must not melt nor sublime — and whose oxide is impervious and adherent. In other words, it is the physical properties of the oxide (refractoriness, density, plasticity, permeability, and such) that must receive consideration.

In view of this it is well to consider those refractories used in industry, and in particular in metallurgical processes. These refractories are based on silica, alumina, and chrome oxide, or lime and magnesia

(used in the basic steel refining methods), or zirconia, beryllia, and thoria (used for laboratory equipment), or lastly the rare earth oxides (for incandescent gas mantles).

If iron is to be the base metal, calcium and magnesium must be omitted from this list of possibilities since they do not alloy with iron. Among the other elements that could be used, we find those very elements that are found in heat-resistant steels, notably chromium, silicon, and aluminum. We have already noted (in 1934) the relationship between the amounts of these different elements necessary to confer oxidation resistance on the steel and the atomic weights of these elements.

There is the possibility of adding several of these elements at once, for example, silicon, chromium, and aluminum, as in "sichromal", but new considerations arise here. For the oxide layer to be protective it must prevent union of the attacking gas and the underlying metal. Omitting the consideration of porous scales (which have been discussed by Pilling and Bedworth and more generally by Trombe) we can see that union of the reactants will occur through compact scales by diffusion of the ions of either metal or oxygen. This immediately involves the ionic and electrolytic conductivity of the scale (Wagner, Mott) and the necessity for a concentration gradient. Thus the best protection will be given by oxides that have no range of solid solution or which are pure homopolar compounds.

In line with these remarks, it should be noted that electrolytic or ionic conductivities behave just the opposite to electronic (metallic) conductivity. High temperatures or solid solution increases these types of conductivities. In his studies on lanthanium and titanium oxides, Trombe finds that solid solution increases conductivity, whereas solid solution of the metals themselves decreases metallic electronic conductivity. Solid solutions of ZrO_2 and MgO furnish an example of solid solution. In this instance we find a direct substitution of magnesium atoms (see André Michel, Société Chimique, Meeting of Jan. 26, 1951).

Consequently, if more than one oxide forms at the surface of the metal, it is important that they exist as a mechanical mixture and not as a solid solution.

These principles for obtaining good oxidation resistance at high temperatures are just as applicable for preventing sulphur attack at high temperatures, a problem that is important to the petroleum industry. In such applications, one must consider the heat of formation, the density, the conductivity, and the possibility of solid solutions of the sulphides.

ALBERT M. PORTEVIN

An Eminent Swiss Metallurgist

SCHAFFHAUSEN, SWITZERLAND

As a member of Tour Group 1 of the First World Metallurgical Congress, I was so struck with the value of an open interchange of information that I reread the biography of Johann Conrad Fischer, founder of the Swiss engineering and steel founding firm which bears his name. He made several journeys to France and England during his life, was an admiring friend of Michael Faraday (early student of alloy steels) and a metallurgical pioneer. His diaries cite many instances where he picked up valuable ideas from his foreign friends, and was able to reciprocate in kind.

Since the very excellent "Chronology of Iron and Steel" compiled by Prof. Stephen L. Goodale of the University of Pittsburgh contains no reference to Fischer's work, I may be pardoned for citing a few items. It is common knowledge that Benjamin Huntsman invented "crucible cast steel" prior to 1750, wherein cemented (high-carbon) steel bar was melted in clay crucibles. However, practical details of process were kept secret, and there were only three manufacturers in England 50 years later. Johann Conrad Fischer was the first continental to take up the idea, and he probably worked out the details independently. He exhibited "homogeneous cast" steel, worked into tools, at the Berne exposition in 1804. Evidence indicates that he used very small crucibles containing about 20 lb. of metal, six in a single furnace, charcoal fired with hot blast. It is also inferred that his raw material was wrought iron (much cheaper than cemented bar) plus some unknown addition, undoubtedly a carbonaceous substance.

The furnace he used was obviously capable of high temperature (in fact, he once showed Faraday a button of melted platinum), so it was only a short step to melt soft steel — even wrought iron. He even-

tually solved the problems connected with sand molds for soft steel castings and made horseshoes and gun lock parts as early as 1840. At the London Exhibition of 1851 he displayed a cast bevel gear.

While British literature and patent records contain references to steel castings in sand molds as far back as 1824, it is certain that the first "commercial" production of steel castings was in Fischer's steel works in Schaffhausen. The exact date cannot be fixed, but was somewhere around 1840.

Johann Conrad Fischer was noted for other things as well — notably, commercial production of nickel steel (called "meteor steel" because meteorites usually contain nickel) which was utilized for coining dies, heavy springs, and other parts where its high hardenability and superior toughness were of advantage. He also transplanted the British-French process of malleable iron into the Teutonic countries.

MAX HUBER
Metallurgist
George Fischer, Ltd.

Explosive Nature of Concentrated Nital

CAMBRIDGE, MASS.

The letter of W. R. Meyer, which appeared in the December 1951 issue of *Metal Progress*, calls attention to the importance of safety in the handling of electrolytes for electropolishing of metals. It seems appropriate to publicize the hazard present in the use of another electrolyte.

A violent explosion of approximately one liter of a solution consisting of 1 part nitric acid and 2 parts methyl alcohol occurred in our laboratory recently. The component liquids had been mixed with the usual precautions, followed by cooling. The solution had then been poured into a bottle which previously contained orthophosphoric acid, but which had been cleaned by rinsing. The explosion occurred approximately two hours after the solution had been poured into the bottle, which was left standing quietly for most of this time. Signs that pressure was building up in the bottle, which was closed by a screw cap, were observed barely in time so that injury by fragments of glass was avoided.

Possibly, some trace of orthophosphoric acid remained in the bottle and helped to catalyze the explosive reaction. However, nital of high concentration has been known to explode in the absence of recognized catalytic effects while being stored. Although such explosions are probably somewhat less powerful than explosions of perchloric acid electrolytes, they constitute a distinct danger. It should be pointed out that several commonly consulted sources of laboratory information gave the composition of this electrolyte, but failed to mention any danger associated with its use.

The nital electrolyte had been intended for electropolishing muntz metal. It was later found that a solution of 600 cc. of orthophosphoric acid (85%) diluted to one liter with distilled water was an excellent electrolyte for this work.

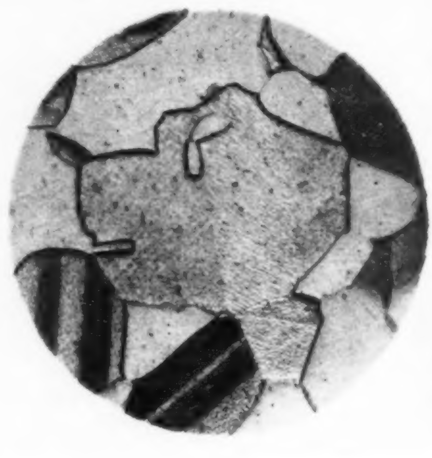
J. E. REYNOLDS, JR.
Instructor
Department of Metallurgy
Massachusetts Institute of Technology

Dogged Metal

DETROIT, MICH.

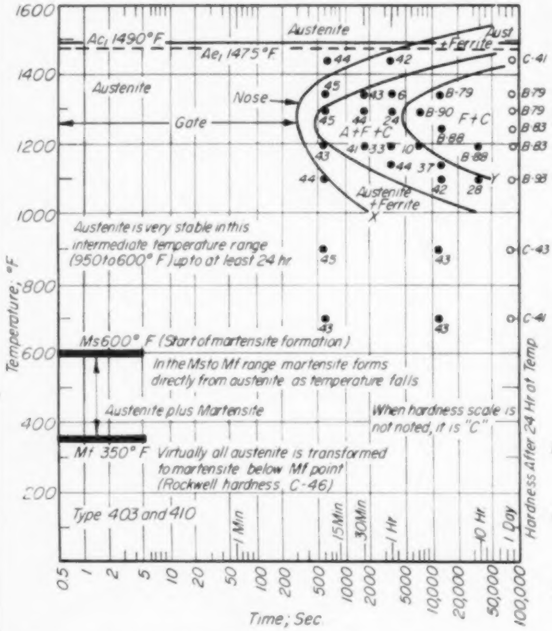
The accompanying photomicrograph should provide convincing proof that even metal can go to the dogs. This dog's head appeared in a sample of Muntz metal (60% Cu, 40% Zn) which was etched with ammonium hydroxide and hydrogen peroxide, 350 ×.

GEORGE L. PARROTT
Metallographer
Michigan Division
Revere Copper and Brass, Inc.

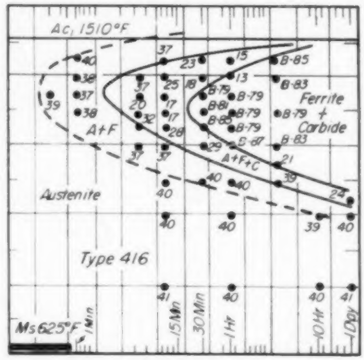


S-Curves for Chromium Stainless Steels

Courtesy Metallurgical Department, Republic Steel Corp.

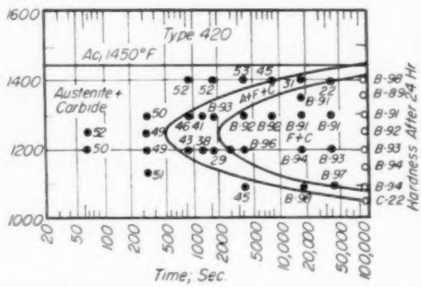


Actual Analysis: 12.3 Cr, 0.62 Si, 0.098 C. The M_s and M_f temperatures were determined with a quenching dilatometer

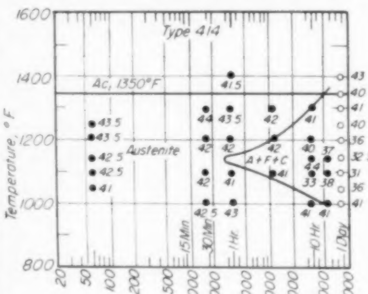


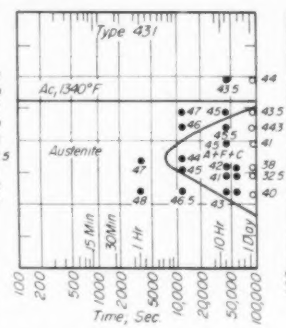
Actual Analysis: 12.4 Cr, 0.94 Mn, 0.44 Mo, 0.35 S, 0.10 C. M_s, 625° F.; M_f, 350° F.

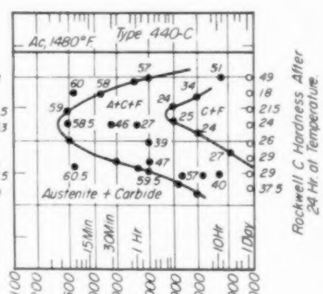
Hardnesses noted are for small samples from a typical heat, quenched in salt at indicated temperatures and times, and then quenched to room temperature to retain the transition structure.



Actual Analysis: 13.0 Cr, 0.42 Mn, 0.10 Mo, 0.013 S, 0.35 C. M_s, 575° F.; M_f, 400° F.







12.65 Cr, 1.86 Ni, 0.10 C. M_s, 525° F.; M_f, 450° F.

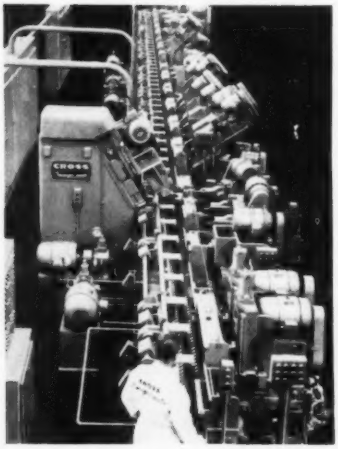
16.42 Cr, 2.44 Ni, 0.16 C. M_s, 290° F.; M_f, 220° F.

16.91 Cr, 0.49 Mo, 1.02 C. M_s, 340° F.; M_f, 140° F.

Hardnesses decrease with increasing time-at-temperature, the minimum hardness generally being reached after 3 hr. Each of these steels has pronounced air-hardening characteristics, and each exhibits an apparently stable region of austenite between 1000° F. and the M_s temperature.

These steels are well suited to heat treatment by martempering. Most satisfactory method for softening Types 414 and 431 is by subcritical annealing at 1275° F.

The Cross Company increases production, eliminates distortion and scale



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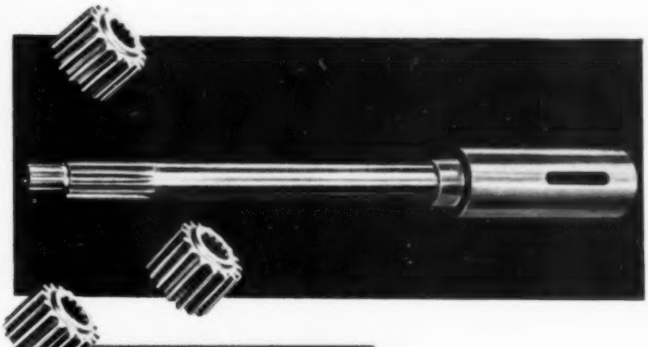

THE TRANSFER-MATIC

Important in the manufacture of this Cross Transfer-matic for the production of automatic transmission housings is the heat treatment of its spindles and gears.

THE PARTS

Spindles and gears are made of A.I.S.I. E-6150 steel. They are brought up to a temperature of 1550°F in AEROHEAT 1200, quenched at 600°F in AEROHEAT 300 and aircooled. Finished hardness: approximately Rockwell C45.

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By Thomas J. Dolan, Research Professor of Theoretical and Applied Mechanics
University of Illinois, Urbana

Problems of Metallic Fatigue at High Temperature

An article in the March issue of *Metal Progress* discussed ways and means of appraising metals for high-temperature service. It was shown that in the laboratory tests for strength and endurance the investigator makes every effort to maintain steady test conditions. For example, in a creep test, the temperature, load and atmosphere are rigidly constant. In a fatigue test, the temperature, cycle of loading, and atmosphere are constant. While this is necessary if reproducible and comparable results are to be secured, they fall far short of predicting conditions in service, wherein there are almost certain to be large variations in temperature and in nature, cycle, and intensity of stress. Consequently the reported properties of refractory alloys at high temperature are to be accepted with reserve and in the light of as much service experience as obtainable.

The text and illustrations to follow will now discuss some specific alloys and some special tests for severe services at high temperatures.

In addition to high mechanical strength at elevated temperature, it is also desirable that an alloy exhibit *(a)* good ductility, *(b)* resistance to erosion, oxidation or chemical attack, *(c)* high fatigue strength against mechanical or thermal stresses, and *(d)* adequate stability (the ability to resist prolonged service at elevated temperature without significant deterioration of important mechanical properties).

Prior to World War II, alloys in this field were principally of the nickel-chromium family, and are rather fully described in "Metals Handbook", 1948 edition, p. 549. A wide variety of complex combinations has been studied in the past ten years, based on cobalt, chromium, iron or nickel, together with smaller amounts of molybdenum, tungsten, vanadium, columbium, aluminum, titanium or tantalum to increase high-temperature strength. Most of the available information on these complex materials has been provided by sponsored research during the war (primarily on contracts with National Defense Research Council and National Advisory Committee for Aeronautics). Use of cast alloys in preference to forged is based on their superior properties in both creep and stress-to-rupture tests of long duration. The short-time high-temperature properties of castings, however, are definitely lower than those of the wrought materials.

Wide variations in cross section of most turbine blades and similar equipment are accompanied by variations in grain size, region to region, in either forging or casting, with corresponding variation in ordinary mechanical properties. Little information appears to be available regarding the effect of metallurgical factors such as grain size on the high-temperature fatigue strength. Toolin and Mochel, in *Proceedings*, American Society for Testing Materials, Vol. 47, 1947, p. 677, indicate that the metallurgical treatment for optimum *fatigue* properties may be somewhat different from that required for optimum *creep* properties. If so, some compromise must be reached in selecting the initial metallurgical treatment and processing methods.

Precision castings often have a coarse grain in comparison with the similar wrought materials; this is sometimes considered desirable for good creep resistance except where single grains occupy the full cross section of highly stressed parts or where wide variations in the modulus of elasticity result. However, Grant found that a certain degree of coarseness of structure should not be exceeded because grain orientation will

*Professor Dolan's complete paper is entitled "Past Work on the Fatigue of Metals in the High-Temperature Field", and comprises Technical Report No. 17 to Project NR-031-005, Office of Naval Research, U. S. Navy, Contract N6-ori-71, Task Order IV. The study was conducted in the department of theoretical and applied mechanics of the University of Illinois. Acknowledgment is due P. Mathur for assistance in collecting references and to F. Pintak, who aided in preparation of illustrations.

play too large a role, sometimes causing early failure (*Transactions*, American Society for Metals, Vol. 39, 1937, p. 335). In one instance Toolin and Mochel found that fine-grained specimens had better fatigue strength at 1200° F. than another group with coarser grain.

Most of the high-temperature alloys of both the ferritic and austenitic types maintain their strength at elevated temperatures through a continued aging with time, thus being metallurgically unstable in use. Precipitation of complex phases within the alloys may alter the mechanical properties to a marked extent. Losses in ductility or serious embrittlement may occur in certain of the stainless and heat resisting alloy steels; other types may recrystallize and grow large grains on prolonged heating. Ductility and notch impact resistance of austenitic Cr-Ni-Fe alloys may be markedly decreased by prolonged exposure to elevated temperatures (as indicated by Payson and Savage, *Transactions*, American Society for Metals, 1947, p. 404), but it is not known what effect these changes may have on the fatigue resistance. Therefore, any data presented for mechanical properties are applicable only to the particular heats processed, heat treatments utilized, and duration of the tests.

The danger exists, of course, that "overaging" — with consequent loss of fatigue strength or other desired properties — may occur after considerable time at high temperature. Since the severity of the harmful effect and the structural changes are a function of the total time in service, this consideration may not be particularly important in those units designed for only a few hundred hours' service, but it is of primary importance where the material is expected to perform continuously for many years.

It is usually assumed that the cyclic stress or previous stress history does not affect the metallurgical character of the material or its properties in a manner different from that which would occur from static stress of similar magnitude. Probably these assumptions are unjustified; cyclic stressing may accelerate solid-state transformations or cause slip or other forms of lattice distortions different from those caused by static loads. "Damping" studies on aluminum alloys indicate that vibratory stress sufficiently prolonged may produce changes in metallurgical conditions that are normally associated with increased temperature, aging, and annealing. Under sustained static loading at elevated temperatures, changes in hardness have been observed in widely used precipitation hardening alloys.

Based on a study of approximately 100 experimental alloys, Freeman, Reynolds, and White ("High-Temperature Alloys Developed for Aircraft Turbosuperchargers and Gas Turbines", Symposium on Materials for Gas Turbines, American Society for Testing Materials, 1946) concluded that a systematic relationship between chemical composition and static mechanical properties does not exist, primarily because heat treatment and fabrication strongly influence the properties. Some of the fundamental reasons for variations in properties at high temperatures are not understood; strain hardening from cold work, and size and distribution of complex precipitated compounds appear to be controlling factors. Prior heat treatment may influence the static properties of wrought alloys at 1700 and 1800° F. It may be inferred from these observations on static tests that a similar (or even greater) variability may be expected in fatigue strength as a result of heat treatment, processing and fabrication procedure.

When tested at temperatures ranging from 400 to 800° F., aluminum alloys are subjected to combined creep and fatigue somewhat analogous to the conditions in alloy steels and high-temperature alloys above 1000° F. Jackson, Cross, and Berry found that the tensile strengths of aluminum alloys 18S-T, 32S-T, and 24S-T decreased above 350° F. as the testing temperature increased; the tensile strength of each alloy was also affected by the length of time the specimen was held at temperature before beginning the test. As a generalization, it might be estimated that the static tensile and yield strengths decrease as a function of the logarithm of the time at temperature. Consequently, these investigators concluded that the fatigue cycle frequency is an important factor. (See N.A.C.A. Technical Note No. 1469, March 1949.)

Perhaps the most complete and systematic survey of the fatigue properties of a wide variety of high-temperature alloys is contained in the above-cited work of Toolin and Mochel. They present more than 70 fatigue curves obtained at 1200 and 1500° F. on various alloys tested in reversed bending

with zero mean stress. The specimen was a fixed cantilever beam, vibrated at a frequency of 120 cycles per sec. (roughly 10 million cycles in 24 hr.) in a machine of the magnetic resonant vibratory type. Test specimens were of two sizes — either 0.550 or 0.333 in. in critical diameter. The smaller specimen was utilized mainly for precision cast specimens, which were tested with sandblasted as-cast surfaces; all others were polished.

The following data are scaled from S-N diagrams of Ni-Cr-Fe alloys tested at 1200° F. in the above manner:

Material	Stress for Failure 10^6 Cycles	10^8 Cycles
16-25-6		46,000
Hoskins 502	44,000	39,000
GT-45	43,000	39,000
Gamma columbium	40,000	33,000
25-20	38,000	29,000
25-12	32,000	23,000

Though most of the curves are relatively flat, they trend toward a continuing downward slope even after 100 million cycles of stress. Hence it is important to state the number of cycles for which a high-temperature fatigue strength is given.

Similar characteristics are shown by the S-N diagrams in Fig. 1 for precision-cast specimens of several alloys tested at 1500° F. Some of the specimens aged during the test and increased in strength with time (and number of cycles); the endurance curves therefore were probably much flatter than if the materials had been stable at the test temperatures.

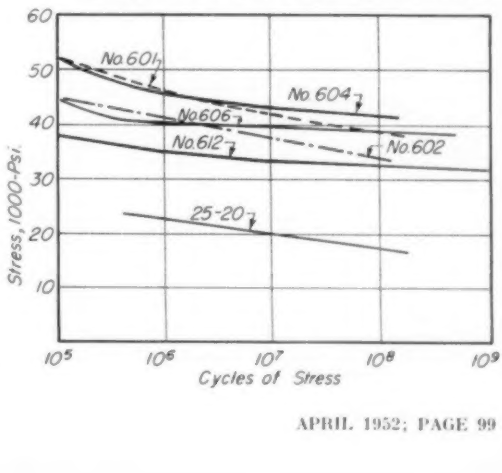
Toolin and Mochel found that for any specific alloy group, those having higher before-test hardness generally showed superior endurance properties. However, because of the instability of the as-cast specimens during a test, the before-test hardness of these alloys had less significance. Fatigue strength varied considerably between the materials in each alloy group, and of course between the alloys in different groups. Other factors besides chemical composition exercised a considerable effect on the fatigue characteristics at 1200 to 1500° F. For example, after an optimum treatment for high creep strength, one alloy showed a fatigue strength of 52,000 psi.; with a modified heat treatment, it was better than 80,000 psi.

Tables I and II show data for the alloys exhibiting the highest fatigue strength at 100 million cycles of stress at 1200 and 1500° F. respectively. These values show vast improvement over a 0.17% carbon steel reported by Moore and Alleman, which had a fatigue strength of 8000 psi. for 10 million cycles at 1200° F. They are also considerably above the results reported by Cross in 1934 on low-carbon and high-carbon 18-8 steel, ranging from 20,000 and 23,000 psi. for cast 18-8 to 30,000 and 32,000 psi. for the rolled alloy at 1200° F.

For several of the alloys tested by Toolin and Mochel the wrought form gave the higher fatigue strength. While there were only two cast metals in the first 12 at 1200° F. (Table I), five of them were listed in the highest 12 at 1500° F.

In general, the wrought alloys exhibit somewhat superior *fatigue* resistance, whereas casting may often leave the metal in a metallurgical condition more resistant to *creep*. In the high-temperature ranges for which an interaction of creep and fatigue occurs, it becomes difficult to predict which of these two will limit the strength. At the excessive temperatures where creep becomes the predominant action, the cast alloys may prove to be superior to the same metals in wrought form, but at lower temperatures (say in the region of 1000 to 1200° F. for the special alloys mentioned) it seems likely that the metallurgical condition and surface preparation should be designed to give optimum *fatigue* life, particularly if cyclic stresses of high frequency are to be resisted. On the other hand, if the fluctuations of stress are

Fig. 1 — S-N Curves for Some Precision-Cast Alloys at 1500° F. According to Toolin and Mochel. For code numbers and compositions see Table I; for comparison with wrought alloys see Table II



High-Temperature Fatigue Data

not a major consideration, an entirely different metallurgical processing might be desirable to promote optimum creep strength or resistance to static stress-rupture.

Fatigue strength of many of these alloys exceeds the static tension stress that would be expected to produce rupture in 1000 hr. at the same temperatures. This is also in line with the observation of Moore on carbon steel and of Cross on 18-8 that "the S-N curves indicate that a design based upon allowable deformation within the life of the material in service will not result in a fatigue failure". This statement is, of course, based on the assumption that the total deformation (primarily creep) would normally be relatively small.

One might predict that the creep taking place in a fatigue test would be somewhat more pronounced when the stress cycle varies from zero to a maximum in an axial load test than in reversed bending or completely reversed cycles of axial loading. The mean stress existing in the "zero to maximum" stress cycle is one half of the maximum, whereas the mean stress in reversed bending is nominally zero. Therefore, the effect of creep should be more significant with higher mean stress.

At high temperatures (and correspondingly large creep rates) the damage produced by a steady stress may exceed the progressive damage from a superimposed cyclic stress. As the temperature is raised, the relation between stress amplitude and *number* of repetitions sustained to fracture is gradually transformed into a relation between the mean stress and the *time* to fracture. Therefore, fatigue design at exceedingly high temperatures may become primarily a design for creep; the effect of the alternation can be disregarded if the mean stress is relatively high. At moderately high temperatures (for which the creep rate is small and the corresponding static creep-to-rupture stress is relatively high) longer times would be required for the damaging effects of creep to be manifested. Under these conditions, and particularly for conditions in which the mean stress is zero, the progressive damage associated with the repeated

Table II — Alloys in Order of Fatigue Strength at 1500° F.

Number	Name	Fatigue Strength	
		1500° F.	1200° F.
102	S-816	47,000	70,000
104	Vitallium, rolled	44,000	63,000
101	Midvale GTA	42,000	71,000
604	Vitallium, cast	41,000	44,000
301	A.H. Inconel "X"	40,000	65,000
606	61, Stellite 23, cast	38,000	44,000
309	K-42-B	38,000	52,000
601	6059, cast	38,000	63,000
202	Hastelloy B	35,000	66,000*
602	X 40, cast	34,000	56,000
109	N-155, low carbon	33,000	61,000*
612	S-816, cast	32,000	

*This test on an alloy of somewhat different composition. See Table I.

Table I — Highest Alloys Tested, in Order of Fatigue Strength† at 1200° F.

No.	Name	C	Mn	Si	Cr	Ni	Mo	Co	W	Cb	Ti	Al	Fe	Fatigue Strength
101	Midvale GTA‡	0.19	0.65	0.64	19.91	32.10	....	30.05	5.41	4.00	....	....	Bal.	71,000
102	S-816	0.36	0.72	0.19	18.40	20.23	3.72	45.63	4.23	3.04	....	....	Bal.	70,000
612	S-816, cast	0.38	0.82	0.25	18.87	19.70	4.04	45.64	4.71	3.43	....	....	Bal.	......
201	Hastelloy B	0.12	1.20	0.52	0.27	60.83	27.10	.....	....	....	....	....	9.96	66,000
202	Hastelloy B	0.04	0.44	0.26	.....	64.42	29.37	.....	....	....	....	....	4.20	......
301	A.H. Inconel "X"‡	0.04	0.50	0.27	14.52	73.31	....	.....	....	1.17	2.36	0.67	7.06	65,000
304	K-42-B	0.05*	0.7	0.59	18*	42*	....	22*	....	....	2.17	0.48	....	63,000
104	Vitallium, rolled	0.22	0.65	0.53	27.42	2.28	5.53	62.20	....	....	....	....	0.70	63,000
601	6059, cast	0.37	....	0.52	25.8	34.8	4.72	33.5	....	....	....	....	0.65	63,000
105	N-155‡	0.15	1.46	0.42	20.84	20.58	3.18	20.48	2.26	1.06	....	....	Bal.	61,000
109	N-155, low carbon‡	0.06*	....	....	20*	20*	3*	20*	2*	1*	....	....	Bal.	......
602	X 40, cast	0.54	1.02	0.61	25.46	10.27	0.21	50.28	6.74	....	....	....	....	56,000
106	S-590	0.47	1.35	0.82	19.40	19.07	4.03	19.26	4.00	3.98	....	....	Bal.	55,000
308	Refractaloy 26	0.05	0.65	0.72	17.9	37*	2.80	20*	....	....	2.60	0.30	Bal.	52,000
309	K-42-B	0.05	...	0.60	18*	42*	....	22*	....	....	2.45	0.37	Bal.	52,000
108	Timken No. 2	0.14	1.56	0.92	17.64	27.65	9.52	35.60	....	....	....	....	Bal.	50,000
606	61, Stellite 23, cast	0.45*	....	....	28*	2*	....	64*	6*	....	....	....	....	44,000
604	Vitallium, cast	0.25*	....	....	28*	2*	6*	64*	....	....	....	....	....	44,000

*Type analysis.

†Fatigue strength at 100,000,000 cycles, psi.

‡Additional elements: 0.15% N in Midvale GTA; 0.02% Cu in Inconel "X"; 0.15% N in N-155.

Data from "High-Temperature Fatigue Strength of Several Gas Turbine Alloys", by R. R. Toolin and N. L. Mochel, *Proceedings*, American Society for Testing Materials, Vol. 47, 1947, p. 677.

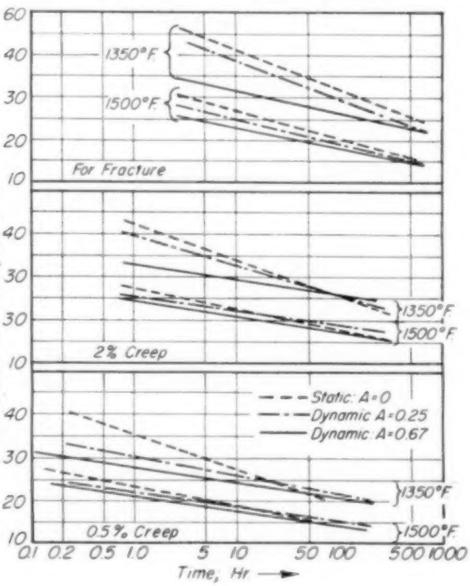
loading (the cycle effect) becomes more significant.

Lazan, in "Dynamic Creep and Rupture Properties of Temperature-Resistant Materials Under Tensile Fatigue Stress" (*Proceedings*, American Society for Testing Materials, 1949, p. 757), presents definite information regarding such superimposed effects at temperatures of 1350 and 1500° F. He tested alloys N-155, S-816, Vitallium, and 19-9DL for creep, time-to-rupture, and unidirectional tension on which was superimposed an alternating cyclic stress (at a frequency of 3600 cycles per min. whose amplitude was either one quarter or two thirds the mean stress).

Typical results are shown in Fig. 2. At 1500° F. the superposition of an alternating stress did not significantly affect the time to rupture — the three lines are not too divergent. At 1350° F., however, the cyclic stress had a more pronounced influence in decreasing the total life of a specimen, particularly for tests of relatively short duration (when the stresses were high).

The allowable creep or rupture stresses for 200-hr. life were not appreciably affected by superposition of alternating stresses; the lines in Fig. 2 practically intersect at that time. An exception is rupture at 1350° F. It occurred at 200 hr. under a steady mean tensile stress of about 29,000 psi., but the allowable mean stress was reduced to 25,000 psi. when an alternating stress of as much as 17,000 psi. was superimposed.

Fig. 2 — Effect of Superimposing Alternating Loads of 25% or 67% of Mean Stress on Time to Rupture of N-155 at 1350 and 1500° F. (Lazan, *Proceedings*, A.S.T.M.) A is ratio between vibration amplitude and mean stress

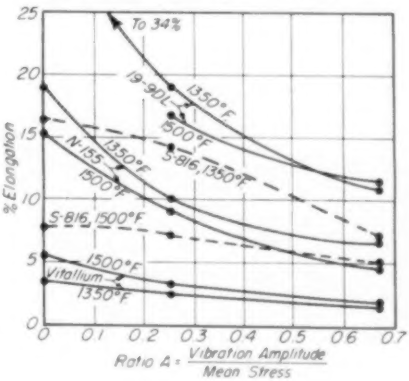


RELATIVE DUCTILITY RATINGS

However, as indicated in Fig. 3, the relative ductility rating in a static tensile test is quite different from that in cyclic loading. There seems to be a tendency for elongation to decrease as the ratio of the alternating stress to the mean stress is increased. Since the decrease in elongation varied from 29 to 63% of the static value for the different materials, the ductility under static loading may be significantly different from the ductility under dynamic loading.

For purposes of comparison, Lazan defined a "mean dynamic to static stress equivalence ratio E" as indicating the ratio of the allowable mean stress S_m under dynamic loading to the equivalent static stress S_e which caused the same creep or rupture behavior. If E is larger than unity, it indicates that the additional cyclic stress increased the life or reduced the creep; if E is smaller than unity, an accelerated creep or rupture was caused by the cyclic stress.

Fig. 3 — Effect of Superimposing Alternating Loads on Mean Stress on Elongation of Specimen at Fracture. (Lazan, *Proceedings*, A.S.T.M.)



Tests on Aluminum and Cast Iron

Figure 4 shows average values for the several alloys tested of this ratio E for rupture and for 0.5 or 2% creep at the end of various time intervals. The solid lines show data obtained using an alternating stress $S_a = 0.67\ S_m$ and the dashed lines for $S_a = 0.25\ S_m$. It is interesting to note that all creep and rupture data at 1500° F. for $S_a \div S_m = 0.25$ show average E larger than unity; that indicates an important fact that the superposition of an alternating stress equal to one quarter the mean stress produced less rapid damage than would have occurred if the mean stress were applied as a steady load. However, for larger amplitudes of alternating stress ($S_a \div S_m = 0.67$) or for the lower temperature (1350° F.) the cyclic stress accelerated the creep and rupture (values of E were less than 1.0).

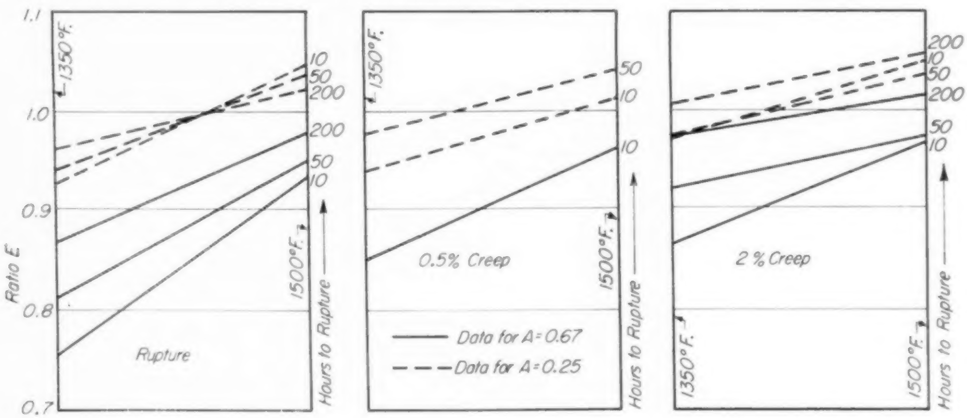
Lazan observes that "the importance of cyclic stress as an accelerator of creep and rupture decreases with increasing temperatures and, in fact, at sufficiently high temperatures, cyclic stress may even decelerate creep and rupture". Data obtained by Mond Nickel Co. indicate that cyclic stress may actually strengthen the material against creep when the maximum cyclic stress is in excess of the rupture stress for that particular temperature.

At 1350° F., however, the superposition of 67% alternating stress reduced the allowable static stress in Lazan's tests by as much as 25%. In general, the shorter the hours to failure (high mean stress), the greater the reduction of allowable stress caused by the superposition of alternating stress. Thus, in apparatus designed for short service at relatively high stress levels, the acceleration of creep by repeated stressing at high temperatures may reduce the allowable stresses substantially below those which would be indicated solely by rupture considerations.

Tests made by Manjoine on 14S-T aluminum alloy at 400° F. are shown in Fig. 5. An alternating stress whose amplitude was 10% of the mean stress was applied at a frequency of 20 cycles per sec. These data indicate that up to about 200 hr. the time to rupture under this type of pulsating load (upper solid line) was shorter than for a constant load equal to the mean stress (dashed lines), but the reverse was true for tests at low stress levels (the lines cross at 200 hr.), so that the allowable mean stress for rupture in 300 hr. was actually increased by adding an alternating stress. The same inversion was observed in creep rates above and below 4×10^{-5} per hr. These results appear to represent peculiar trends similar to those noted by Lazan on heat resistant alloys at 1350 and 1500° F.

While cast iron is not generally used for stress-carrying members operating at high temperature, interesting questions are raised by the data obtained by Collins. In the 1948 *Proceedings* of the American Society for Testing Materials (p. 696) he gives endurance limits of an austenitic cast iron as shown on the next page.

Fig. 4 — Lazan's Diagram Showing That Superimposed Alternating Loads Increase Resistance to Deformation When E Is Greater Than Unity. E is ratio of allowable mean stress under dynamic loading to the equivalent static stress for the same creep behavior or rupture life



Test Temperature	Unnotched Specimen	Notched Specimen
70° F.	14,000	12,600
400	17,000	13,200
700	14,000	14,500
900	10,000	13,300
1160	12,000	12,000

The stress in the notched specimens was figured on the net area. The austenitic cast iron varied little in fatigue strength in reversed bending (at 2500 cycles per min.) from 70 to 1160° F. Of even greater importance is the fact that specimens with a small hole transverse to the axis of the cylindrical specimen (diameter one tenth the diameter of the specimen) had fatigue strengths as great as those of the unnotched specimens. In other words, the presence of a serious stress raiser did not weaken the cast iron, though data indicate that this would have reduced the fatigue strength of steel by at least a factor of two. If high-temperature alloys are found to be notch-sensitive at working temperatures, their fatigue strengths may not be greatly superior to this cast iron.

DAMPING CAPACITIES

Damping capacities of the high-temperature alloys are too nearly alike for the differences to be of practical significance, and apparently none of the present-day high-temperature alloys seem to exhibit high damping capacity. Therefore, alloys having fairly high fatigue strength have usually been selected. Some designers try to add to the natural damping characteristics by mechanical assembly of components rather than by welding. The extremely high inherent damping capacity of some material such as cast iron would prove highly beneficial in minimizing the stress range for which the blade must be designed.

In evaluating past work in the field of high-temperature fatigue, or in planning a research program for future study, the following factors should be given careful consideration:

1. The instability of (and effect of changes in) the metallurgical structure with elapsed time at the elevated temperature.

Service Conditions Defined

2. The influence of erosion, surface oxidation, and chemical changes induced by the environment.

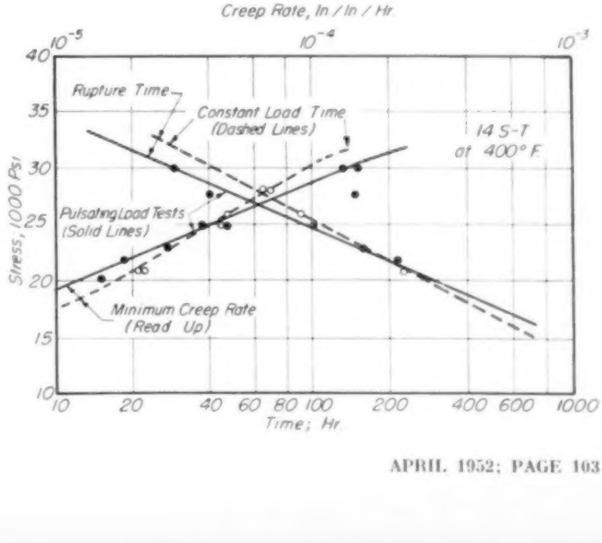
3. The relative influence of time (for creep to accumulate) as compared with the frequency with which the repeated stresses are applied.

4. Modifications in the behavior caused by the superposition of a mean or steady stress, which tends to accelerate creep but which may not markedly influence the fatigue characteristics.

To obtain fundamental data on the combinations of circumstances that lead to failure in high-temperature fatigue, the interactions of the above four parameters (which define the service condition) must be quantitatively evaluated. The parts which chemical and metallurgical change play in altering the properties during sustained exposure to high temperatures have not been fully recognized as having a major effect on laboratory test data. As an illustration, let us review the effect of pulsating loads on time-to-fracture when the temperature is high enough to cause appreciable creep.

Limited tests made by Greenwood and Cole (reported in *Metallurgia*, Vol. 39, 1949, p. 121) indicate that the creep rate of a lead alloy was markedly increased by the presence of a superimposed vibration. Manjoine's

Fig. 5 — Creep and Rupture Tests of 14S-T Aluminum Alloy Disks at 400° F. Under Constant Load (Dashed Lines) and With an Alternating Load 10% as Large Superimposed. (Manjoine, *Proceedings*, American Society for Testing Materials, 1949, p. 788)



Fundamental Information Needed

tests on aluminum alloys and Lazan's on high-temperature alloys cited in Fig. 2 to 5 also present convincing evidence that the over-all creep may be accelerated by a superimposed alternating load for certain combinations of temperature and mean stress. Thus, in some instances the presence of fluctuating load may limit the life of a member not only by the possibility of fatigue fracture but also by the indirect process of stimulating excessive creep. Nevertheless, for other sets of conditions (involving an increase of temperature in Lazan's tests or for the lower stress levels in Manjoine's tests) there may be a beneficial effect (decreased creep and longer time to fracture).

The reason for this perplexing phenomenon is obscure, but it might be explained by the probable structural changes. At high temperatures an accelerated precipitation of hardening constituents may be catalyzed by the alternating stress, and this strengthening might be accompanied by a beneficial relaxation of the microstresses developed around the precipitated constituents. At lower temperatures both of these beneficial actions would progress at a low rate per cycle, and would be counteracted by slip and structural damage (on the crystalline scale) caused by the stress repetition. At somewhat lower stress levels, however, for which the time of test is greatly increased (and for which the fatigue damage progresses at a very low rate per cycle) the beneficial effects may again have sufficient time to improve the strength of the material during the test (or to prolong its life).

A strong need exists for fundamental information on the nature of the phenomena limiting the life of a metal in high-temperature fatigue; such information should eventually lead to more accurate methods for predicting the useful service life of specific components. Several important questions (to which there is at present no definite answer) might be formulated as follows:

1. Creep may or may not be accompanied by plastic flow (that is, slip within the crystals). Freudenthal (in "Types of Inelasticity of Structural Materials and Procedures of Design", Institute of Aeronautical Sciences, Preprint No. 258, January 1950) suggests that peak stresses are relieved by plastic flow but are not influenced by purely viscous creep. On the other hand, concentrations of strain around localized regions of abrupt change in section are not relieved by flow. Is it stress or strain that is of prime importance, and how is the criterion of failure governed by the interaction of creep and plastic flow?

2. Elevated temperatures increase the mobility or accelerate the place change of atoms, which should facilitate greater deformation prior to fracture. However, the breakup of crystal grains by slip is opposed by the tendency to re-form into a limiting minimum stable grain size, so that recrystallization or grain growth may result (particularly after plastic deformation). Other metallurgical changes such as precipitation, aging, and phase changes might be accelerated by repeated stressing. Does this instability and continual change of structure lead to marked modifications in fracture characteristics? Are the flow and fracture criteria functions of (or altered by) the load cycle, or are they primarily dependent on time and temperature?

3. For steels at room temperature, slip is a discontinuous process governed mainly by the resolved (or critical) shear stress level. At elevated temperatures, however, relaxation and recovery may allow further slip to proceed at the same stress level. The disordered material within slip bands and along the crystalline boundaries is very sensitive in its behavior to the effects of time and temperature. Does the fact that hot metals do not exhibit a definite endurance limit relate itself to the inability of the material to strain harden and resist further inelastic action?

4. To what extent do surface effects such as erosion, oxidation, chemical attack and film formation serve to initiate or nucleate a fatigue fracture at elevated temperatures?

These are only a few of the questions stemming from a lack of basic information.

In summary, the author can only re-emphasize the need for further research and carefully planned experimental programs which seek an answer to some of these questions or which would serve to clarify the rather complex interactions occurring in high-temperature service. Only after extensive new contributions are made to our present sketchy understanding of high-temperature fatigue can the significance of present data be interpreted and adequate design procedures be evolved.

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

How NITROGEN Refines Grain Size...

Produces Harder, Stronger, Tougher Chromium Steels

When nitrogen is added to high-chromium steel, it greatly refines the grain size of the metal and materially increases its strength, toughness, hardness, and wear resistance—without sacrificing ductility or reducing corrosion resistance. For these reasons, nitrogen-bearing chromium steels are well suited for cutlery, turbine blades, and various machinery parts that are subject to extreme wear.

Added to Steel In Ferrochrome

Nitrogen is usually added to chromium steels in the form of nitrogen-bearing ferrochrome containing 0.75 per cent and up of nitrogen, 70 per cent chromium, and a maximum of 0.10 per cent carbon. Depending upon the chromium content of the steel, which can range between 12 and 30 per cent, the nitrogen content may vary between 0.06 and 0.20 per cent. The amount of nitrogen added to high-chromium steels should be 1 part of nitrogen to between 100 and 200 parts of chromium, depending upon the chromium content of the steel.

Nitrogen-bearing ferrochrome is added to the furnace in the same manner as ordinary ferrochrome. Nitrogen recovery will average about 90 per cent.

Improves Cutlery Steel

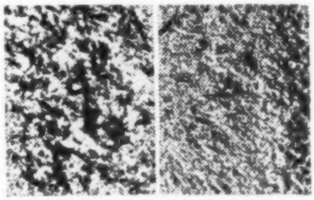
Cutlery steels and other martensitic stainless steels, such as the 12 to 14 per cent chromium low-carbon steels that are used for turbine blades, are hardenable by heat-treatment. Hardenability and strength increase with the carbon content. And, since nitrogen is a more powerful austenite-former than carbon, it is sometimes used as a substitute for part of the carbon, or as a supplement to the carbon, to increase the strength and hardenability of these steels.

Nitrogen has distinct advantages over carbon for this purpose because ductility, toughness, and corrosion resistance are retained when nitrogen is added to steel. It increases the hardness of cutlery steels without detrimentally affecting toughness or corrosion resistance. The effect of small additions of nitrogen in increasing the hardness of cutlery steels is shown in the table below.

Reduces Grain Growth During Hot-Working

The ferritic high-chromium stainless steels to which nitrogen is added have a finer grain size than ferritic steels without nitrogen, which are comparatively coarse-grained. These include the 16 to 18 per cent chromium wrought steels, high-chromium steels containing small percentages of nickel, and both the cast and wrought 20 to 30 per cent chromium steels. The function of nitrogen when added to the ferritic high-chromium steels is to preserve a fine grain size.

The nitrogen-bearing, high-chromium wrought steels are more readily rolled and forged than comparable steels containing no nitrogen, because grain growth is in-



Note the extent to which nitrogen refines the grain size of those specimens containing about 27 per cent chromium and 0.35 per cent carbon. The specimen at the left contains 0.05 per cent nitrogen; the one at the right, 0.30 per cent nitrogen.

hibited during hot-working operations. Greater yields are therefore obtained in rolling and fabricating. Also, strength and toughness are increased as a result of the grain refinement caused by the nitrogen addition.

Greater Strength for Austenitic Steels

Small percentages of nitrogen will increase the yield point and tensile strength of the austenitic chromium-nickel steels. These include the well-known 18 per cent chromium, 8 per cent nickel steels, and also the 25 per cent chromium, 12 per cent nickel steels. The improvement in strength is gained at practically no sacrifice of workability. Furthermore, nitrogen promotes the formation of austenite.

Metallurgical Service Available

ELECTROMET nitrogen-bearing ferrochrome is furnished in the following standard analysis:

Chromium	67 to 71 %
Carbon	0.10 % max.
Silicon	0.30 to 1.00 %
Nitrogen	0.75 % approx., or higher if desired.

It is produced in lump sizes of 25 lb. by 8 mesh, or 15 lb. by 8 mesh; also, in a crushed size of 2 in. by down.

If you would like additional information about the production of nitrogen-bearing steels, ask to have one of our metallurgists call, or ask for the booklet, "Nitrogen In Chromium Alloy Steels." Write to the address given above or to the ELECTROMET office nearest to you. Offices are in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York and San Francisco. In Canada: Welland, Ontario.

Effect of Nitrogen on the Hardness of Cutlery Steels*

% Cr.	% C	% Si	% Mn	% Mo	% N	Rockwell C Hardness	Brinell Hardness Numbers (by conversion)
13.15	0.12	0.30	0.38	...	0.03	41	387
13.25	0.13	0.29	0.42	...	0.10	48	460
13.36	0.23	0.28	0.40	...	0.03	46	437
13.27	0.21	0.34	0.32	...	0.08	51	496
12.70	0.32	0.30	0.37	...	0.04	50	484
13.41	0.35	0.31	0.41	...	0.11	56	560
17.37	0.41	0.32	0.41	0.75	0.036	41	382
17.25	0.44	0.30	0.42	0.75	0.09	53	522
17.30	0.66	0.29	0.38	...	0.03	51	496
17.08	0.60	0.31	0.40	...	0.11	55	547
17.26	0.80	0.28	0.39	0.76	0.032	52	509
17.25	0.80	0.27	0.45	0.74	0.09	57	573

*Steels oil-quenched from 950°C. Held 5 hr. at 200°C. and air-cooled.

Personal Mention

William H. White

William E. Ruder

WILLIAM H. WHITE, retiring manager of toolsteel sales for the Detroit district of Allegheny Ludlum Steel Corp., began his working career as a machinist, later becoming tool and die maker before entering sales work in the toolsteel industry. He joined the former Atlas Steel Co. as manager of sales of the Cleveland district in 1921, a position which he retained during a series of mergers which absorbed Atlas into Allegheny Ludlum. In 1942 Mr. White went to Atlas Steels Ltd., Welland, Ont., as director of sales. This company was operated by the British government and worked on war materials. In 1946 Mr. White rejoined Allegheny Ludlum as district manager of toolsteel sales, the position from which he has now retired. He has been prominent in various technical societies for many years. He is a past president of the Cleveland Chapter of the American Society for Metals and is a member of the Detroit Chapter at the present time. He is also a member of the Detroit Chapters of the American Society of Tool Engineers and the Society of Automotive Engineers.

S. T. Jazwinski, formerly with the Ford Motor Co., Dearborn, Mich., is now chief research metallurgist with the Central Iron and Steel Co., Harrisburg, Pa.

WILLIAM E. RUDER, an authority on permanent magnets and magnetic materials, has retired from the research laboratory of the General Electric Co., Schenectady, N. Y., after more than 44 years service. Although one of the early pioneers in metallurgy in the United States, his most important work has been concerned with magnetic materials. His early work in Alnico, an alloy of aluminum, nickel, cobalt and iron, resulted in permanent magnets far more powerful than those previously made of carbon steel. He was also responsible for development of the so-called "soft" magnetic steels which hold a minimum of permanent magnetism. Mr. Ruder also originated the commercially important "calorizing" process for coating iron and other metals with aluminum. This process, introduced in 1912, is widely used to prevent scaling due to oxidation of metal surfaces. After serving as head of the laboratory's metallurgy division for 12 years, in 1950 Mr. Ruder was named manager of the then newly organized metallurgy research department. From 1933 to 1950 he was a director of the Allegheny Ludlum Steel Corp., Pittsburgh, one of the first companies to manufacture the special steels which he developed for transformers. During World War II he was consultant for the metallurgy division of the War Production Board and recently was named consultant to the Metallurgical Advisory Board Committee of the National Academy of Sciences. This board advises the armed forces and government agencies on metallurgy problems. Mr. Ruder is a member of the American Institute of Mining and Metallurgical Engineers, the American Society for Advancement of Science and the American Ordnance Association. He has been particularly active in the American Iron and Steel Institute.

L. W. Prestin has been elected vice-president of Sunbeam Corp., Chicago, in charge of the industrial furnace division.

Henry A. Mullen, manager of the resistance welding division of Ampco Metal, Inc., Milwaukee, has recently been appointed a member of the Advisory Committee of the Resistance Welder Electrode Manufacturers Industry which works in conjunction with the National Production Authority.

A. J. McCullough has been appointed to the newly created post of regional industrial manager of the Brown Instrument Division, Minneapolis-Honeywell Regulator Co., Cleveland.

A. S. Kasper has been promoted from research metallurgist to staff engineer for the Houdaille-Hershey Corp., Detroit.

David F. Greenawalt has recently taken a position as a metallurgical engineer with Rich Manufacturing Corp., Battle Creek, Mich.

Robert M. Bracy, a recent graduate of the University of Kansas, is now with Black, Sivalls & Bryson, Inc., Kansas City. He is metallurgical assistant to Robert T. Howard, chief metallurgist.

Harvey B. Nudelman, who recently graduated from the University of Illinois, has been appointed a research assis'ant in the metals department at Armour Research Foundation of Illinois Institute of Technology, Chicago.

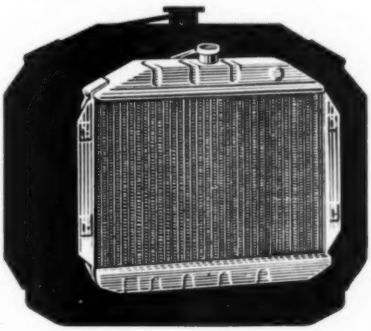
James M. Warfield is employed by the Caterpillar Tractor Co., Peoria, Ill., where he is working in the metallurgical laboratory.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Substitution of materials is of considerable concern to many manufacturers these days. Never before have we seen so much interest in the subject. However, it is by no means new to Revere, which has always held to the principle of recommending the metal that will best serve the customer. Thus, we have often suggested switching from one metal or alloy to another, with the object of lowering costs, increasing production, improving service, or all three.

When based on a detailed study of all the factors involved, substitution at times can be extremely valuable. In fact, the ever-increasing quality and service to be found in American products is due in part to the continued search for better materials, and their adoption when found. Better materials, better design, finer workmanship—these are part of American progress.



But there are instances, of course, when no practical substitute can be found, when only one material offers just the right combination of good qualities required for a given application. Take the automobile radiator. This has always been made of copper, because copper is the one and thus far only metal that perfectly meets all the requirements of manufacture and service. To make a radiator, very thin copper sheet and strip must be crimped, bent and otherwise formed. Copper's easy workability makes it ideal from the manufacturing standpoint. After assembly, the radiator is cleaned, and made water-tight by dipping in a bath of hot solder. Copper is exceptionally easy to solder. When in service on a car, truck or bus, the radiator must not rust, and must resist corrosion by water and anti-freeze. Copper is notable for its resistance to corrosion in such use. The radiator must also cool the water by radiating its heat into the air stream; copper has the highest heat conductivity of all commercial metals. A copper radiator thus is the most efficient and durable. It should outlast the car unless accidentally damaged, and when the injury is not so great as to make replacement necessary, the nearest shop can make repairs easily.

Recently it has been suggested that automotive radiators should be made of aluminum. However, both copper and aluminum are temporarily in short supply, and therefore to substitute one for the other does not appear to be practical. Beyond that, we do not believe —based upon experience to date—that aluminum's qualities, fine though they are, necessarily make it suitable for automotive radiators. In addition, the difficulties of retooling in the factory and repairs in the field must be considered. Revere fabricates both copper and aluminum, and we have reason to believe that our impartial advice to stay with copper for automotive radiators is concurred in by radiator manufacturers.

When you are tempted to substitute one material for another in your product, no matter what it may be, make certain you obtain all the facts as to costs, production, service. Your suppliers will be glad to collaborate with you in studying the effects of a proposed change. We suggest you take full advantage of their knowledge and experience.

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Personals

Marvin L. Nelson ⊕, formerly chief engineer at Solar's Grand Avenue Works in Des Moines, Iowa, has been appointed works manager of Solar Aircraft Co.'s new Wakonda Works, Des Moines.

R. M. Woodside ⊕ has been promoted to district industrial manager of the Brown Instrument Division of Minneapolis-Honeywell Regulator Co., Cleveland.

Raymond J. Zale ⊕ has resigned from his position as a special representative for Darwin & Milner, Inc., Cleveland, to accept a position as a sales metallurgist with Firth Sterling Steel & Carbide Corp., Pittsburgh.

Rod Schrivener ⊕, after five years of sales engineering work with Kaiser Aluminum and Chemical Sales Inc., Chicago, has been promoted to manager of the market research section in the company's New York Aluminum Development Division.

William F. Cassedy, Jr., ⊕ is now president of Aircraft Radio Corp., Boonton, N. J.

Bruce A. Hainsworth ⊕, formerly with the H. K. Ferguson Co., Cleveland District, is now director of engineering for E. R. Squibb & Sons, New Brunswick, N. J.

H. Scott Bandy ⊕ has been appointed quality control manager of Chase Aircraft Co., Inc., West Trenton, N. J.

Richard M. Hedstrom ⊕, a recent graduate of the South Dakota School of Mines and Technology, has accepted a position with the Caterpillar Tractor Co., Peoria, Ill.

Adolph J. Lena ⊕ is now research metallurgist in the research labora'ory of the Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Philip C. Miller ⊕, who recently graduated from Rensselaer Polytechnic Institute, is now research metallurgist at the Babcock & Wilcox Research and Development Center, Alliance, Ohio.

William J. Fretague ⊕ recently joined the staff of the metallurgy division of Oak Ridge National Laboratory. He is a former graduate student and research fellow of the department of metallurgy, University of Notre Dame.

William Gibb ⊕ is now chief inspector of the Atlas Foundry & Machine Co., Tacoma, Wash.

Donald T. Surprenant ⊕ has accepted a position as research and development engineer at the metallurgical laboratory of the Dow Chemical Co., Midland, Mich.

Jean G. Louvier ⊕, formerly with the Western Cartridge Co., East Alton, Ill., is now a metallurgist with the Mueller Brass Co., Port Huron, Mich.

R. T. Myer ⊕ has been transferred to the Massena (N. Y.) Fabricating Works by the Aluminum Co. of America. He was formerly chief metallurgist at the New Kensington Works and will occupy the same position at his new location.

Jay E. Fowler ⊕ is now employed as plant metallurgist at Michigan Standard Alloys, Inc., Benton Harbor, Mich.

A. C. Paulson ⊕ has been appointed manager of the St. Paul branch of the Crucible Steel Co. He was formerly a district representative in Rockford, Ill.

Personals

D. F. Rundle, formerly with Campbell Wyant & Cannon Foundry Co., Muskegon, Mich., has taken a position as research metallurgist with Chrysler Corp.'s Central Engineering Division, Detroit.

L. F. Overhold has been appointed assistant manager of engineering for the International Harvester Co. of Australia Pty., Inc., Victoria.

W. J. Harris, Jr., formerly with the Naval Research Laboratory, has accepted the post of executive secretary to the Minerals and Metals Advisory Board, National Research Council, Washington, D. C.

Lowell T. Smith has been appointed assistant metallurgical engineer in the metals department, Research and Development Division, Olin Industries, Inc., East Alton, Ill. He was formerly production supervisor in the tube mill, Lewin-Mathes Corp., Monsanto, Ill.

Alan R. Pels has joined the staff of the research department of the Bridgeport Brass Co., Bridgeport, Conn. where he will be employed as a research metallurgist.

Walter Mathesius has retired from the presidency of Geneva Steel Co., Geneva, Ill., and is now consultant for the Koppers Co. Inc., Freyn Engineering Department, Chicago.

Mitchell H. Weisman has been recalled to active duty as a lieutenant in the U. S. Air Forces and is now assigned to the Operations and Plans Office, Research Division, Wright Air Development Center at Wright-Patterson Air Force Base, Dayton, Ohio.

W. K. Culp has been promoted to major in the U. S. Air Force and is now a radar instructor at Mather Air Force Base, Calif.

Franklin W. Daniels and Michael J. Bolton of General Electric Co.'s transformer and allied products division (Pittsfield, Mass.) were awarded the Mathewson Gold Medal recently by the American Institute of Mining and Metallurgical Engineers.

Willard N. Lynch, Jr., recently became president of the Keystone Drawn Steel Co., Spring City, Pa.

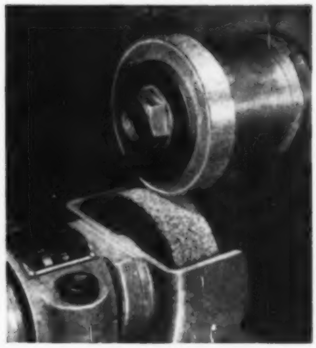
N. E. Philpot is project manager, Industrial Branch, Productivity and Technical Assistance Division of the Mutual Security Agency, Washington, D. C.

Richard M. Treco, formerly with Sylvania Electric Products Inc., Bayside, N. Y., is research metallurgist at the Bridgeport Brass Co., Bridgeport, Conn.

George M. Staples III has joined the staff of Columbia University as an assistant in the department of chemical engineering.

Edgar Landerman has recently accepted a position as manufacturing engineer with the metals joining laboratory, Westinghouse Corp., East Pittsburgh, Pa.

P. E. Holder, formerly a sales representative in the American Cyanamid Co.'s Chicago district, has been appointed assistant district manager of the St. Louis district for the company's industrial chemicals division.



TRUE THE SURFACE. With this set-up true two diamond wheels at a time. Surfaces become uniform and perfectly flat. Usually takes about 15 to 30 minutes.

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Osborn Brushes

OSBORN POWER, MAINTENANCE AND PAINT BRUSHES AND FOUNDRY MOLDING MACHINES

Personals

Guillian H. Clamer, president of the Ajax Group Co., Philadelphia, **William A. Darrah**, president of the Continental Industrial Engineers, Inc., Chicago, and **Adolph W. Machlet**, chairman of the board, American Gas Furnace Co., Elizabeth, N. J., were awarded the Trinks Industrial Heating Award for outstanding contributions in the field of industrial heating. The award was established in honor of Wilabald Trinks, professor emeritus of mechanical engineering at Carnegie Institute of Technology, authority on the subject of industrial heating processes, industrial furnaces, and combustion problems.

Robert C. Kleindinst of Buffalo has been appointed representative for New York State (excepting the metropolitan area) and Northern Pennsylvania by the Dollin Corp., Irvington, N. J., producers of zinc and aluminum die castings.

Nathaniel C. Fick, a member of the Department of Defense Research and Development Board, has been appointed director of the panel on metals and minerals of the newly established Committee on Materials.

William B. Klee, Jr., formerly with Copperweld Steel Co., Glassport, Pa., now heads the Damascus Tube Co., Greenville, Pa.

Jerome W. Kaufman, formerly chief metallurgical engineer of the Naval Air Development Center at Johnsville, Pa., has been recalled to active duty as a captain, U. S. Army, and is now training at Aberdeen Proving Ground, Md., for subsequent procurement duties with the Ordnance Corps.

Albert J. Miller, who graduated from the University of Pittsburgh recently, has been employed as foreman of general services in the openhearth division of U. S. Steel's Duquesne District Works.

Robert E. Fisher, formerly associated with the General Motors Corp., is now with the atomic energy division of E. I. duPont de Nemours & Co., Wilmington, Del.

Charles B. Reymann is now materials and process engineer for the Hayes Aircraft Corp., Birmingham, Ala.

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CITIES SERVICE

Friction and Wear at High Speeds and Pressures*

The fundamental investigations described in this report give some very interesting data which could be useful for research on such applications as retainers for high-speed bearings subject to "starvation lubrication" or dry friction. This work was initiated because of failure of materials now used for antifriction bearing retainers in applications subject to temperatures over 500° F., with periods of little or no lubrication and high sliding pressures.

Jet engines and superchargers are applications in which bearing retainers have given considerable trouble. The critical phase of most high-speed bearing employment is at starting and for a short period thereafter. If little or no lubricant is present — as with rotor bearings of turbine-type aircraft engines after shutdown, which results from lubricants being vaporized from the bearing parts — dry metallic contact can occur between the retainers and the raceway or rolling elements.

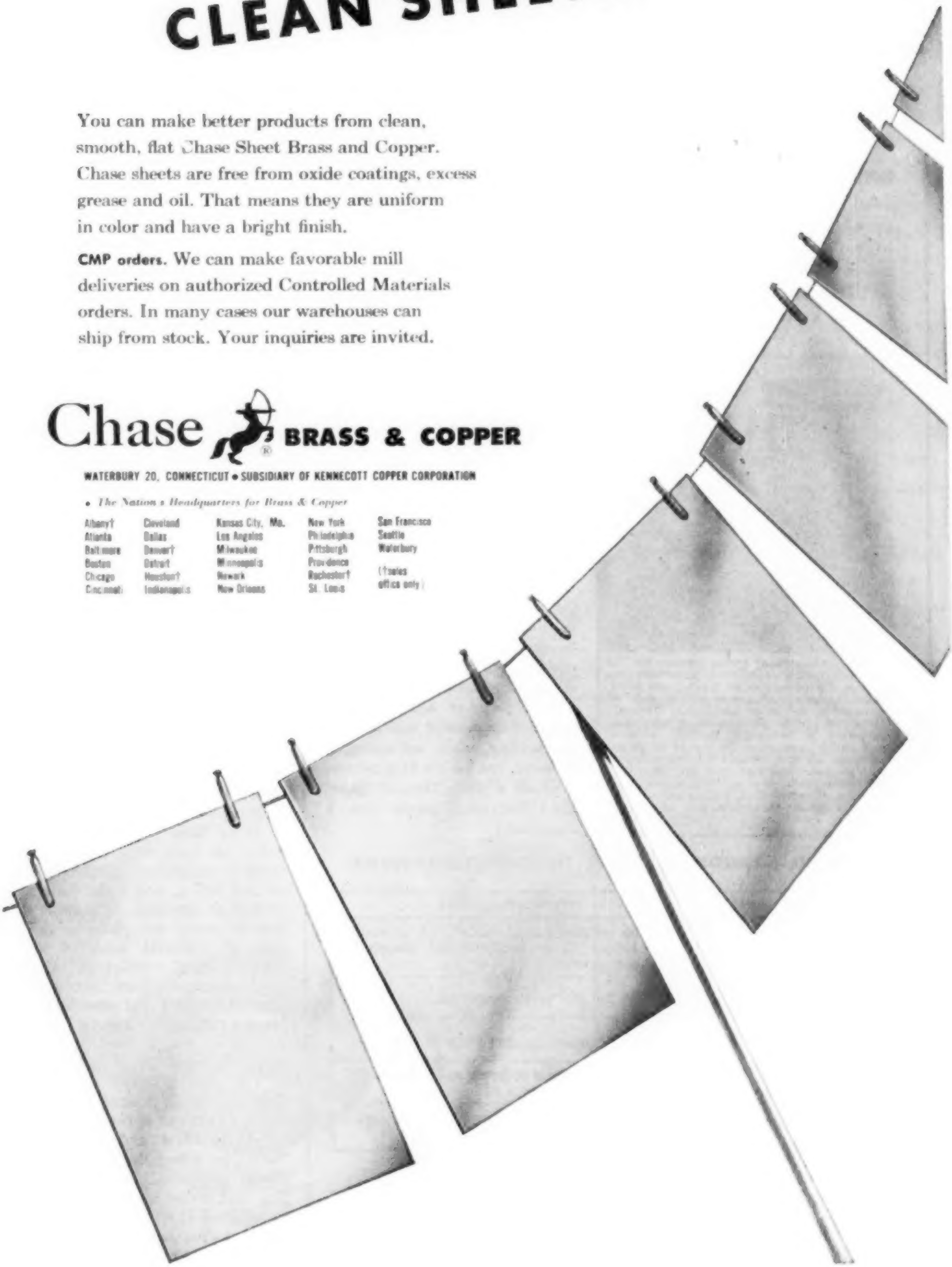
At the high rotative speeds of these bearings (over 12,000 r.p.m.) and possible high pressures at points of local contact, it is not surprising that most materials fail due to excessive wear and galling. In addition to the normal pressures developed by the centrifugal force and driving load, stress concentrations result from roll skewing. Loads at the ends of separator pockets are sometimes formed; these produce plastic deformation of the material as distinct from abrasive wear. A successful separator material must have an adequate yield strength at operating temperature to inhibit plastic deformation.

The test apparatus consisted of a 13-in. diameter steel disk (S.A.E. 52100) hardened to Rockwell C-60 and circumferentially ground to a finish of 10 to 15 micro-in. (rms.) simulating the surface roughness of antifriction bearing cage locating members.

The ¾-in. diameter cylindrical specimens were of brass, Monel, 24S-T aluminum, Nichrome V, bronze, beryllium copper, nodular

(Continued on p. 116)

*Abstract of "Preliminary Investigation of Wear and Friction Properties Under Sliding Conditions of Materials Suitable for Cages of Rolling-Contact Bearings", by R. L. Johnson, M. A. Swikert and E. E. Bisson, Technical Note 2384, June 1951, National Advisory Committee for Aeronautics.



Friction and Wear at High Speeds and Pressures

(Continued from p. 114)

and gray cast iron. One end was hemispherical and contacted the flat face of the steel disk which was rotated by a vertical shaft. After the specimens and disk were suitably cleaned before each test, the load was applied on the top of the specimens by a pneumatic diaphragm for friction tests and dead weights for wear tests.

Dry friction tests were made with a load of 100 g. and sliding speeds of 75 to 18,000 ft. per min. Frictional force was measured by a dynamometer ring equipped with strain gages, readings being obtained on a potentiometer converted to a friction-force indicator. The duration of load, speed and photographing of friction records were controlled by a synchronized timer which operated on a 3-sec. cycle. All dry friction tests were made on the same wear track with the friction readings being made at progressively higher speeds, approximately six readings being taken through the speed range.

Friction of boundary-lubricated surfaces was determined by rubbing a very thin film of a petroleum lubricant (Air Force 3519-2) on the disk using lens tissue. The speed in this test was maintained at 5000 ft. per min. with increasing loads in increments of 119 g. up to a maximum load of 1593 g. until either visible metallic transfer (galling) or friction increase denoted failure. It was believed that the initial lubricant films deposited on the disk were approaching monomolecular thickness at the point of contact.

Wear tests were conducted for 3 hr. on each material under dry surface conditions using two loads, 50 and 269 g., and a constant speed of 5000 ft. per min. The determination for wear was made by the volume of material removed at the hemispherical contact point. This was calculated from the observed area of contact and also by weighing the specimen. Weight loss could be reproduced within ±10% for a given material.

The data obtained for dry friction shows that bronze had the lowest coefficient, approximately 0.20 for light load and low speeds; Nichrome V had the lowest for high speed, followed closely by Monel. The cast irons had a characteristic curve starting at approximately 0.40, rising to a maximum of 0.60 between

(Continued on p. 118)

Customer Reports:

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Factors Affecting the Corrosion Resistance of Stainless Steels

Norman S. Mott
Chief Chemist and Metallurgist
The Cooper Alloy Foundry Co.

Much doubt exists today as to the influence on the corrosion resistance of stainless alloys of such factors as metal surface condition, grain size, cold working, chemical composition, magnetism and passivity. This discussion will attempt to explain these factors and their influence.

1. The smoother the surface of the metal, the better the corrosion resistance; thus ground or machined surfaces are better than those which are sand blasted, and a polished surface is the best.

2. Small grain size in austenitic stainless steels decreases the tendency to intergranular attack, but the general over-all corrosion rate is not affected to any great extent by grain size.

3. Cold working austenitic stainless steels decreases the tendency to intergranular attack through the production of a small grain size and precipitation of carbides along strain lines rather than at the grain boundaries. Its effect on the over-all corrosion rate, however, is to increase it.

4. Chemical elements such as chromium and aluminum are corrosion resistant in oxidizing acids, and others such as nickel, copper and tungsten are corrosion resistant in reducing baths. Some, such as molybdenum and silicon, are resistant to both. Alloyed, these properties may reverse to a certain extent; however, in general, their corrosion tendencies hold true for the more gross additions.

5. Magnetism in stainless steel is produced by the chemical composition balance and/or cold work. Its effect on the corrosion resistance is related only to that effect produced by these sources directly, and not to the magnetism as such. Chromium, silicon, molybdenum, columbium and titanium form a magnetic phase known as ferrite; and nickel, carbon and manganese form the non-magnetic phase austenite. The balance of these elements, considering their relative degrees of potency, determines whether or not the stainless steel is magnetic. The presence of ferrite in moderate amounts (5-10%) in the austenitic stainless alloys greatly decreases the tendency to intergranular corrosion but has little effect on the over-all corrosion rate. Ferritic-type alloys do not corrode intergranularly.

6. Passivity, a condition of nobility on low corrosion rate, is mainly a physicochemical surface characteristic of stainless steel, and is produced mainly by its chromium content. Passivity is first apparent around 12% and is not really effective until about 18% is reached. Additions of nickel increase the passive effect, and thus an 18 chrome 8 nickel alloy is more corrosion resistant than the 18% chrome type. Passivity is further promoted by additions of certain other elements, mainly molybdenum. The exact nature of passivity is still in dispute; however, it is known that while some media promote passivity, others break it down. Air, oxygen, adsorbed gases, nitric or chrome acids, and a high polish promote passivity, and chlorides, hydrochloric or sulfuric acids break it down. In dilute hydrochloric and sulfuric acids, 18-8S and 18-SMo remain passive until a critical percentage or temperature is reached, then passivity breaks down and active violent corrosion proceeds.

Friction and Wear at High Speeds and Pressures

(Continued from p. 116)

2000 and 6000 ft. per min. and returning to 0.40 at high speed.

Under boundary lubricated conditions at a constant speed (5000 ft. per min.) and variable load, the 24S-T aluminum had the lowest coefficient at low loads (400 g.), nodular iron and bronze at high loads, followed closely by Nichrome V. Monel had the most inconsistent friction curve of all, with a spread of more than 100%.

The results of wear tests show that brass, beryllium copper and aluminum are relatively poor, even at low loads. Monel at high loads behaves as badly as brass. The cast irons showed the lowest wear and greatest freedom from galling.

The prevention of galling is attributed to the formation of surface films. Whether a film can form depends on the characteristics of the material and its temperature; for Monel, beryllium copper and Nichrome V it may be due to an unstable oxide film that is formed, giving rise to variable friction and galling. Gray cast iron and nodular iron, on the other hand, would produce graphitic carbon as the deposited film, whereas bronze would produce a lead film.

Nodular cast iron, on the basis of its wear, would be indicated for bearing separator use, provided its strength is adequate for the purpose. Its self-contained graphite apparently provides a nonwelding interface, even at high temperatures. The oxide-forming films, particularly with the Nichrome V material, show interesting possibilities if they can be formed and renewed at all temperatures. Those of Monel apparently are very unstable throughout the temperature range.

COMMENTS BY REVIEWER

The results of this investigation confirm previous experience that the strength of the base material at operating temperatures and pressures is not the criterion for galling failure. Both nodular cast iron and Monel were tested at approximately the same Hertz stress level; yet nodular cast iron had minimum wear. Strength data for these are:

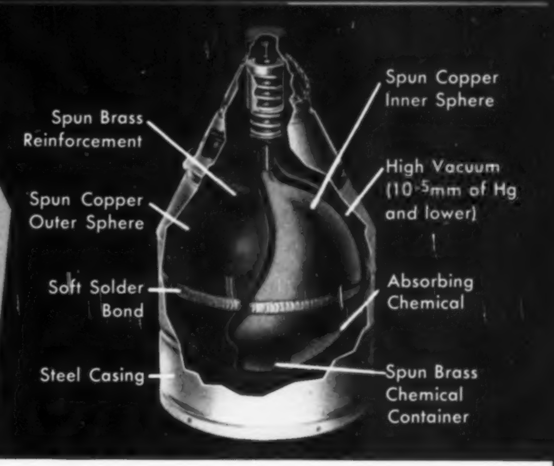
	Tensile Strength	Yield Strength
Nodular Cast Iron	80,000	50,000
Monel	110,000	100,000

The modulus of elasticity for the

(Continued on p. 120)

It's COLD inside these liquid gas containers . . .

and polished copper helps keep 'em that way



Cutaway section of a Hofman "Standard" Liquefied Gas Container, made in a range of sizes from 5 to 2000-liter capacity.

This is Herb Basewit, design draftsman of Hofman Laboratories, Inc., holding an unretouched polished copper inner shell for a 25-liter container. A perforated spun-brass dish soldered on one end holds a chemical which absorbs any leakage of gas into the vacuum.

In the storage and transportation of liquefied gases such as air, oxygen, nitrogen, hydrogen and helium, evaporation losses are the big problem (containers can't be sealed because of explosion risks). If insulation is not adequate for the *minus*-452 F temperatures encountered, losses are costly.

Hofman Laboratories, Inc., of Newark, N. J. took a big forward step and made some radical changes in container design. Resembling a giant picnic vacuum bottle, the "Standard" Hofman Container is constructed of an inner and outer copper sphere separated by an extremely high vacuum. Bulky insulation is eliminated and, through the use of polished copper, surface radiation losses are greatly reduced.

Here, as in many other industrial applications, copper does a multi-purpose job better than any other metal by providing: (1) the ductility and malleability necessary for deep-spinning the hemispheres, (2) an unequalled metal for soldering, and (3) a smooth-surface, fine-grain metal that will readily take a mirror-like finish.

Anaconda Metals are made by The American Brass Company, General Offices: Waterbury 20, Conn. 5285

Here Herb is seen pointing to the hole for exhausting air to obtain vacuum. A solder bond is used to join the copper hemispheres.

ANACONDA

COPPER and BRASS

Friction and Wear at High Speeds and Pressures

(*Continued from p. 118*)

iron is 23 million and for Monel it is 26 million psi.

The explanation as suggested in the paper would appear to be valid, that an active built-in material can produce a surface film having a shear plane of weakness less than the shear strength of either contacting bodies. It is known that effective "boundary lubrication" is due to films deposited on the surface, either from the fluid lubricant (extreme-pressure lubricants) or solid lubricants, such as graphite and molybdenum, or the less effective oxide films.

Because it is impossible to build up effective hydrodynamic lubrication between the sliding members at very high surface speeds due to narrow contacts and insufficient lubricant, it would appear that solid lubricants incorporated into the base material, such as graphite and molybdenum, are the most promising at present. In this respect graphitic steel might also have merit. Powdered metals incorporating low friction-active solids could be effective.

Although these films might be effective for the most severe applications of dry friction, an improvement that might be considered is that of the geometrical shape of separator load-carrying members to obtain the optimum hydrodynamic effect. Apparent contact area as such is not a parameter of effective galling prevention.

While the loads carried in friction tests with "boundary lubrication" show final Hertz pressures of only 640 psi. maximum after 48 sec., it would appear that the range of pressure for effective operation would be something less than the 55,000-psi. yield strength of cast iron to prevent local plastic deformation arising from stress concentrations caused by roller skewing.

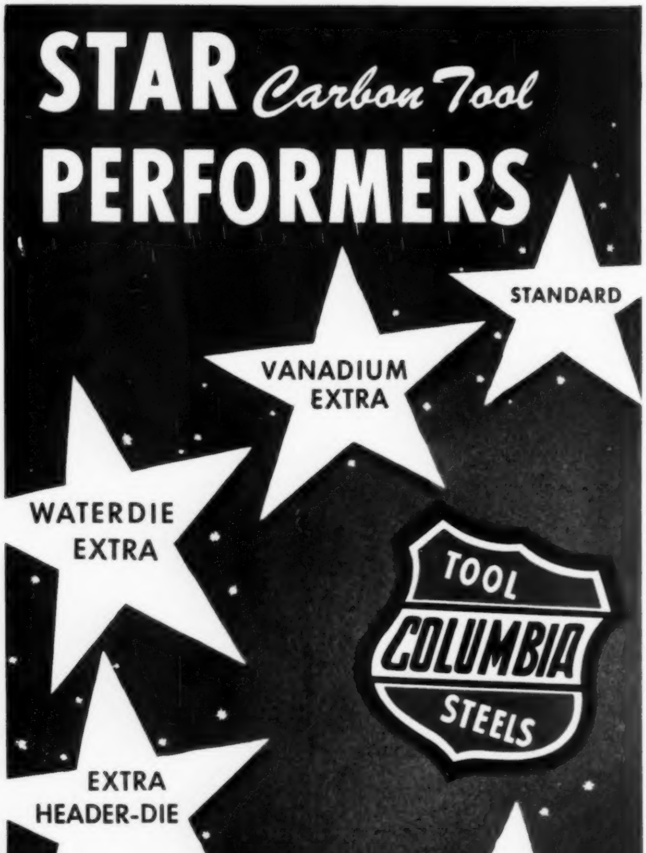
E. G. Boden

The Chromium Plating of Light-Metal Cylinders*

Aluminum alloys have long been realized to be very desirable for cylinders as well as pistons of internal combustion engines. This is because their thermal conductiv-

(*Continued on p. 122*)

*Abstract of "Light Metal Chromed Cylinders", *The Engineer*, Vol. 192, July 27, 1951, p. 115.



The Chromium Plating of Light-Metal Cylinders

(Continued from p. 120)

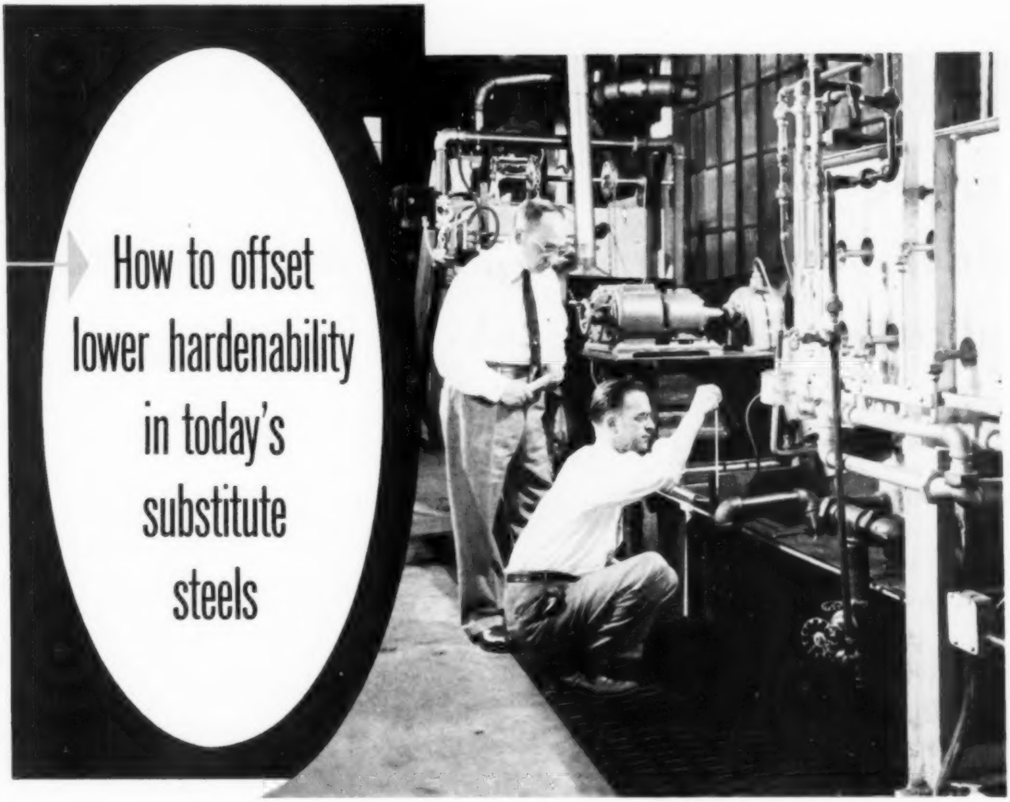
ity is considerably greater than that of cast iron, especially in air-cooled engines (particularly of the two-stroke type). Also, use of these alloys permits matching the thermal expansion of the aluminum pistons so commonly used nowadays so that excessive clearance over the whole temperature range of operation is avoided. On the other hand, its poor abrasion resistance and tendency to gall were long considered to make use of aluminum alloys impracticable.

The earliest successful solution of this problem was to use cast iron cylinder liners in aluminum blocks, thus combining the good friction characteristics of the cast iron liner with the high thermal conductivity of the aluminum block. The liners were either pressed-in or cast-in by a rather ingenious but complicated process. However, neither method was entirely satisfactory. In the first method the heat flow is considerably obstructed by the interface, and the differential thermal expansion of the two materials causes distortion of the cylinder contour as well as causing separation at the interface. The cast-in method is expensive and the thermal barrier provided by the cast iron is still present to some extent.

Independently of these advances a special chromium plating of cast iron cylinder barrels began to make its appearance. Chromium plating has a two-fold advantage: it not only has high abrasion resistance which considerably reduces the wear of cylinder bores in dusty or sandy environment, but it also permits a simple salvage by rebuilding the cylinder wall back to its original diameter. Its value was particularly evident in the engines of planes used in the North African campaign during the recent war, where both the sand abrasion and the engine salvage problems presented a serious problem.

This plating was initially applied to cast iron cylinders but more recently to aluminum alloy cylinders as well; it seems to solve the wear resistance problem of the latter. (It is not, however, the usual "bright chromium" surface used for decorative purposes.) Oil seems to spread with difficulty on this plated surface, and an abrasive particle, because it cannot be imbedded, has no place to go to get

(Continued on p. 124)



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Gulf Super-Quench passes through the vapor stage far more quickly than conventional quenching oils. This means that the cooling rate is extremely fast at the outset, an important factor in the depth and uniformity of hardening. In the succeeding stages Gulf Super-Quench has a slow cooling rate, like that of conventional quenching oils, and therefore has the same minimum tendency toward distortion and cracking.

Greater quenching power of Gulf Super-Quench adds up to greater depth of hardening and more uniform hardness! One of the most practical advantages of Gulf Super-Quench is greater uniformity of results on steels of variable hardenability.

For further information on Gulf Super-Quench, call in a Gulf Sales Engineer today. Write, wire, or phone your nearest Gulf office.

GULF SERVES INDUSTRY

The Chromium Plating of Light-Metal Cylinders

(Continued from p. 122)

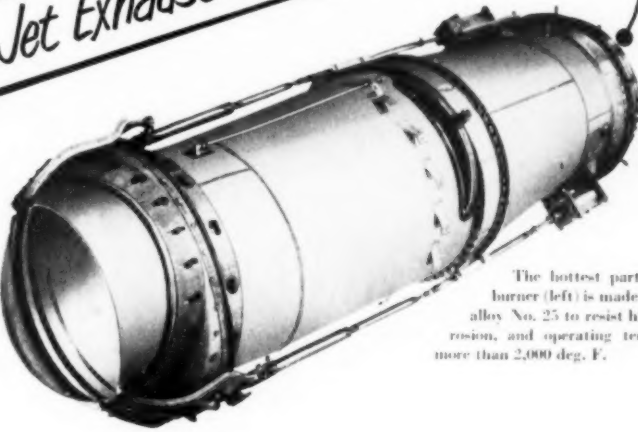
out of the way. A number of special platings have been developed which eliminate these difficulties and provide an excellent cylinder barrel surface in many respects. All of these have this characteristic in common, that the familiar smooth chromium surface is replaced with one in which there are frequent minute indentations. These indentations have the property of *(a)* holding oil, *(b)* interrupting any galling that might start, and *(c)* providing a place for an abrasive or wear particle to escape from between the rubbing surfaces without scoring them.

Such indented or interrupted surfaces have been produced in a number of ways. Possibly the best known is that developed and patented by the H. van der Horst Corp. By this process the chromium is plated on a smooth surface to a depth of 0.002 to 0.003 in. and more than necessary for the final bore size. The cylinder is then removed from the plating tank and put into another tank, containing another solution with the same anodes and the same setup, but in which the current is reversed for a few minutes. As a result, some of the plated chromium is removed, not in a uniform layer but in localized regions, thus producing what is often called a porous chromium surface containing a multitude of pits and depressions evenly dispersed over the whole cylinder wall.

The porous chromium plating of aluminum cylinders, also developed by the van der Horst Corp. during the last war, is not basically different from that for the steel or cast iron cylinder described above, except for the tendency of aluminum to form an oxide layer which prevents its bonding with electrolytic deposits of other metals. To overcome this difficulty the cylinder to be plated is first dipped in a strong solution of caustic and sodium zincate. The caustic dissolves the oxide film to reveal the bare metal and also roughens it slightly which contributes to the indented character of the final surface. The sodium zincate forms a protective film, which is exceedingly thin and even, over the plating surface as the oxide is dissolved but which is readily dissolved in the chromic acid of the subsequent plating bath. After

(Continued on p. 126)

HAYNES alloy No. 25 Harnesses Jet Exhaust at over 2,000°F.



The hottest part of the after-burner (left) is made from HAYNES alloy No. 25 to resist high stress, corrosion, and operating temperatures of more than 2,000 deg. F.

Jet exhaust gases that reach temperatures of more than 2,000 deg. F. and speeds as high as 1,800 m.p.h. are easily handled by the new HAYNES cobalt-base alloy No. 25. In fact, this alloy was one of the few commercially available materials that could even be considered for the hottest parts of the afterburner pictured here.

The afterburner is installed behind the jet engine and increases the thrust of the plane by burning fuel with the unused oxygen in the turbine exhaust. Finding an alloy that would stand up under the heat and stress of this operation was really a tough problem. The material had to be strong at high temperatures and resistant to the oxidizing action of the corrosive exhaust gases. In addition, it had to be capable of fabrication by drawing, forming, and welding.

HAYNES alloy No. 25 has a unique combination of all these properties. For complete information on this alloy, write for the 12-page booklet, "HAYNES Alloy No. 25."

HAYNES Alloys

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The Chromium Plating of Light-Metal Cylinders

(Continued from p. 124)

plating, the cylinder is honed to its accurate diameter; this removes the surface irregularities down to about mid-depth and provides a smooth plateau over which the rubbing load is distributed.

Results obtained by the Mall Tool Co. of Chicago using this method on small portable air-cooled two-stroke engines have been very encouraging. Compared to an engine having a pressed-in steel liner, the plated aluminum cylinder makes possible an engine which is smaller and lighter and yet develops 32% more power.

In Europe the Mahle concern, Stuttgart, have obtained equally encouraging results with aluminum cylinder bores that have indentations in the chromium plating which are made in a somewhat different manner. The cylinder, after the final fine-boring operation, is machined with a knurling tool which leaves a regular pattern of indentations on the surface. Inasmuch as the deposit follows the contour of the base metal, the plated surface has all the characteristics of the latter. That is, evenly dispersed recesses for the retention of lubricant and reception of foreign particles. The useful life of the engine was found to be increased sufficiently to offset the increased cost of the plating step.

Another possibility is to chromium plate only the piston and rings and this is being tested at present by the Mahle concern. If successful, it should be considerably cheaper than plating the cylinders and might easily give a great impetus to a more general adoption of light-metal cylinders, particularly in air-cooled engines for road vehicles.

J. T. Burwell, Jr.

Spheroidal-Graphite Cast Iron for Crankshafts*

Acicular and spheroidal-graphite types of cast iron have found extensive use in Great Britain in internal combustion engine and stationary diesel engine crankshaft castings. From an engineering

*Abstract of "Cast Iron Crankshafts, With Special Reference to Acicular and Spheroidal-Graphite Cast Irons", by A. B. Everest, *Foundry Trade Journal*, Vol. 91, Dec. 6, 1951, p. 643-650.

viewpoint, cast iron crankshafts offer a number of important advantages: reduced weight, reduced machining time, and elimination of heat treating operations — properties which favor their use even when steel is available. Production economy is another benefit.

ACICULAR CAST IRON

Early in the development of cast iron for crankshafts in the U.S.A., alloy composition containing nickel and molybdenum was adopted, as it was found that this alloy combination gave exceptionally high strength. Further study established that these high mechanical properties could be obtained at will by using molybdenum in conjunction with nickel, the latter being varied in relation to the cooling rate or section thickness of the casting. The characteristic structure developed in these nickel-molybdenum cast irons is closely related to "bainite", and this type of cast iron is now known as acicular cast iron.

The tensile strength of acicular cast iron can vary from 55,000 to 77,000 psi. and can be further improved by heat treatment. Its other mechanical properties are correspondingly high — its impact or shock resistance is at least twice that of the best pearlitic cast iron.

The graphite in the normal acicular iron is in the flake form; consequently this iron shares the good damping properties associated with flake-graphite irons and, in common with all the other cast irons, it shows a low notch sensitivity in fatigue tests. Wear resistance of acicular cast iron is excellent. Although its hardness is relatively high, it can be readily machined.

Considerable experience is now available on the use of the nickel-molybdenum acicular cast iron crankshafts in internal combustion engines. The economy in using acicular cast iron crankshafts as compared with the conventional type of steel forging or stamping is substantial.

On engine test, torsional vibration diagrams on a shaft for 6-cylinder diesel engine, developing 240 h.p. at 1500 r.p.m., have shown that the steel crankshaft developed a torsional shear stress of 9100 psi., due to the sixth-order critical speed, and this was reduced to 4250 psi. in the cast iron crankshaft.

Satisfactory fatigue strength is demonstrated by acicular cast iron crankshafts. For example, one maker, who has recently been studying this material for a six-

(Continued on p. 128)

Spheroidal-Graphite Cast Iron for Crankshafts

(Continued from p. 127)

throw marine diesel crankshaft, states that test-bars cut from an extension of the crankshaft casting give a fatigue strength on the plain bar of 21,300 psi. The use of a notch in the test-bar only slightly reduces this figure, and a strength of 20,600 psi. is reported. Under similar conditions of test, the values for steel are normally of the order of 17,000 psi. Torsion fatigue tests on unnotched bars gave 12,000 psi., and similar tests conducted on bars containing a drilled hole, so positioned as to give maximum concentration of stress, gave 8500 psi. Notch sensitivity of cast iron is much less than for steel, with the result that in practice there is appreciably less danger of fatigue failure due to stress concentration by such discontinuities as oil holes.

SPHEROIDAL CAST IRON

Lately, attention has been drawn to a product known variously as spheroidal-graphite cast iron, nodular cast iron or ductile cast iron. The essential characteristic of these irons is that the graphite has assumed the form of compact spherical particles. These have a very much smaller deleterious effect in breaking up the metallic matrix of the metal, allow the properties of the metallic matrix to be more fully realized, and eliminate the innumerable notches which act as stress raisers within the body of normal cast iron.

The mechanical properties of these new cast irons are of a high order, and approach very much more nearly those common to the steel-like matrix of the metal. Their strength under various forms of test is about double that of conventional cast iron. The elastic modulus is high, but of particular interest is the fact that, like other cast irons, the notch sensitivity of the material is low compared to steel, as shown by the relatively low reduction in the endurance-limit figure, which included a notch in the test-piece. The net result of this is that the endurance limit under notched conditions is, for the new material, frequently as high or even greater than that of steel as used for crankshafts.

As would be expected from the form of graphite, the vibration-damping capacity of the new cast irons lies midway between that of

(Continued on p. 146)


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"Every man in our shop is an expert"

says James Henderson

U. S. STEEL MACHINIST

● The machine shops are vitally important at the Homestead District Works Forge Division. If you could visit them, you'd see machines that are really whoppers—like the 96-inch lathe that can turn and bore a 110-ton piece that's 8 feet in diameter, and 66 feet long. If you talked to Machinist James Henderson, who operates the lathe, the conversation might go like this:

YOU: *"How old were you when you started in the mill?"*

HENDERSON: "Fourteen. I started in the Homestead Works as a messenger in 1918."

YOU: *"How long were you a messenger?"*

HENDERSON: "Four years. Then when I was 18, I started as an apprentice machinist in the maintenance shop."

YOU: *"What kind of work did you do?"*

HENDERSON: "Practically everything. First, of course, I had to operate all the machines. It was good training, because in a big mill like this, if something broke down—a big cylinder bushing or a special bolt—we couldn't wait for outside replacements so we'd make new parts for the job. We had to work fast, too, because sometimes a whole production line would be shut down."

YOU: *"What did you do next?"*

HENDERSON: "After almost 20 years in the maintenance shop, I came here. I've been on the 96-inch lathe ever since."

YOU: *"That means you've been a machinist now for 30 years. Did you like coming to the forge department?"*

HENDERSON: "It was the greatest experience I ever had in this mill. In a way, I had to learn all over again. I remember how scared I was the first time I had to bore and ream a long hole through one of these big forgings. It was just like this job—we're boring a hole 25 feet long, to a .001" diameter tolerance."

YOU: *"Do you ever run into any trouble?"*

HENDERSON: "We sure do. Like when we're drilling a hole. You get an awful sinking feeling when the rod comes out without the drill on the end. It's a break-off. The drill breaks off and stays galled in the hole. Sometimes we spend as much as 8 hours trying to pull that drill out with special tongs."

YOU: *"I guess a mistake would be mighty expensive."*

HENDERSON: "Yes. Here, a mistake could cost thousands of dollars. But we don't make many mistakes."

YOU: *"What would you say is the most important thing about making quality forgings?"*

HENDERSON: "Well, you've got to have the steel and the machines. But I think the men are most important. Like here, the furnace man, pressman, machinist, and heat treater all have to work together. Any one man can foul up a job. We almost never have trouble, so I figure almost every man in the shop is an expert."

• • •

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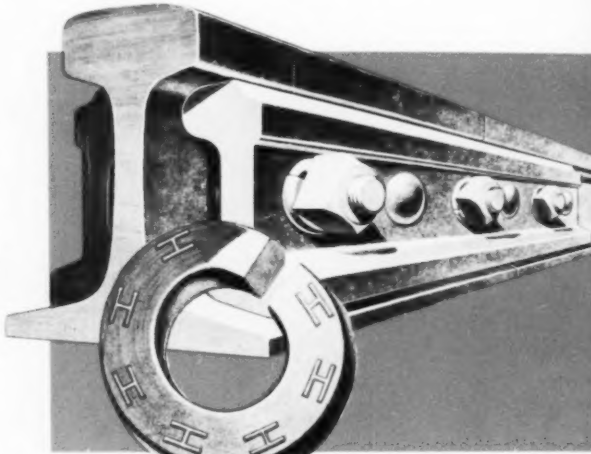

HUBBARD & COMPANY, Tool Division, Pittsburgh, Pa., is a major producer of rail joint spring washers. These vital washers are used on the bolts of the joint bars that connect sections of railroad rails. Battering and wear at the rail ends is reduced due to the high bolt tension caused by the reactive pressure of these CARILLOY steel washers.

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Here are the actual test results on a typical production run at Hubbard & Company. At left is the finished washer ready for delivery. Middle picture shows the washer after the 90° twist test required by specifications. As shown at the right, Hubbard spring washers will consistently withstand a twist test far greater than required.

At Hubbard, this variable speed conveyor removes spring washers from the quench tank on a precise time cycle.

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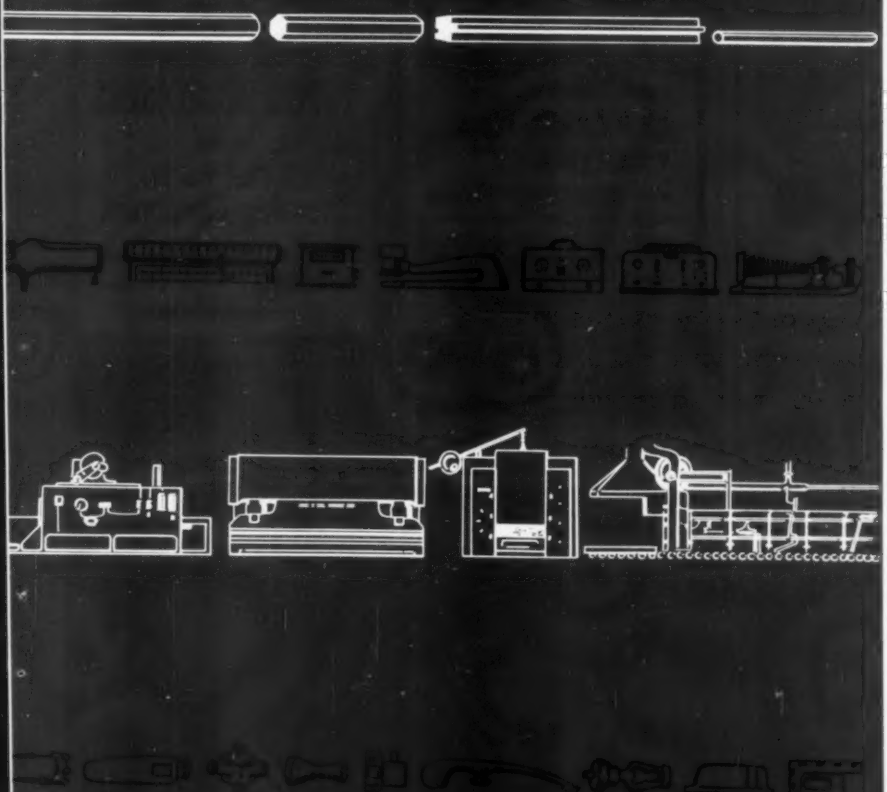

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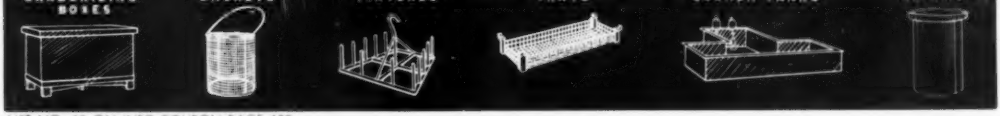
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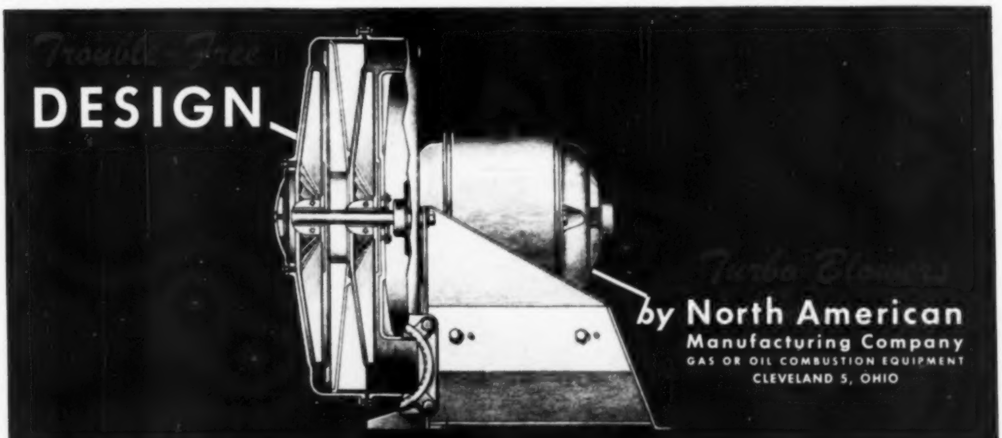
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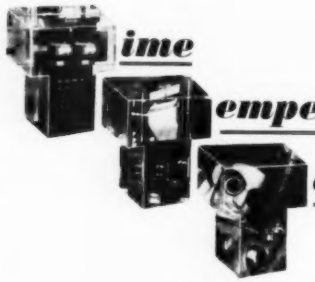

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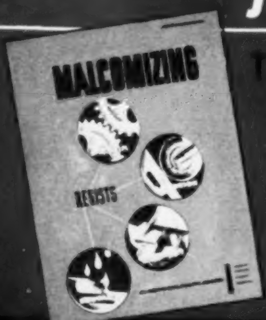

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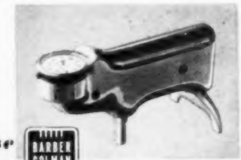

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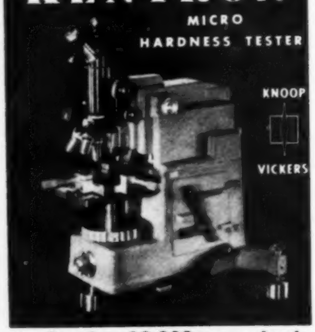

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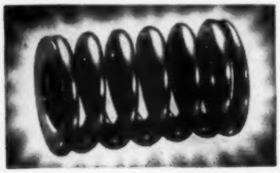

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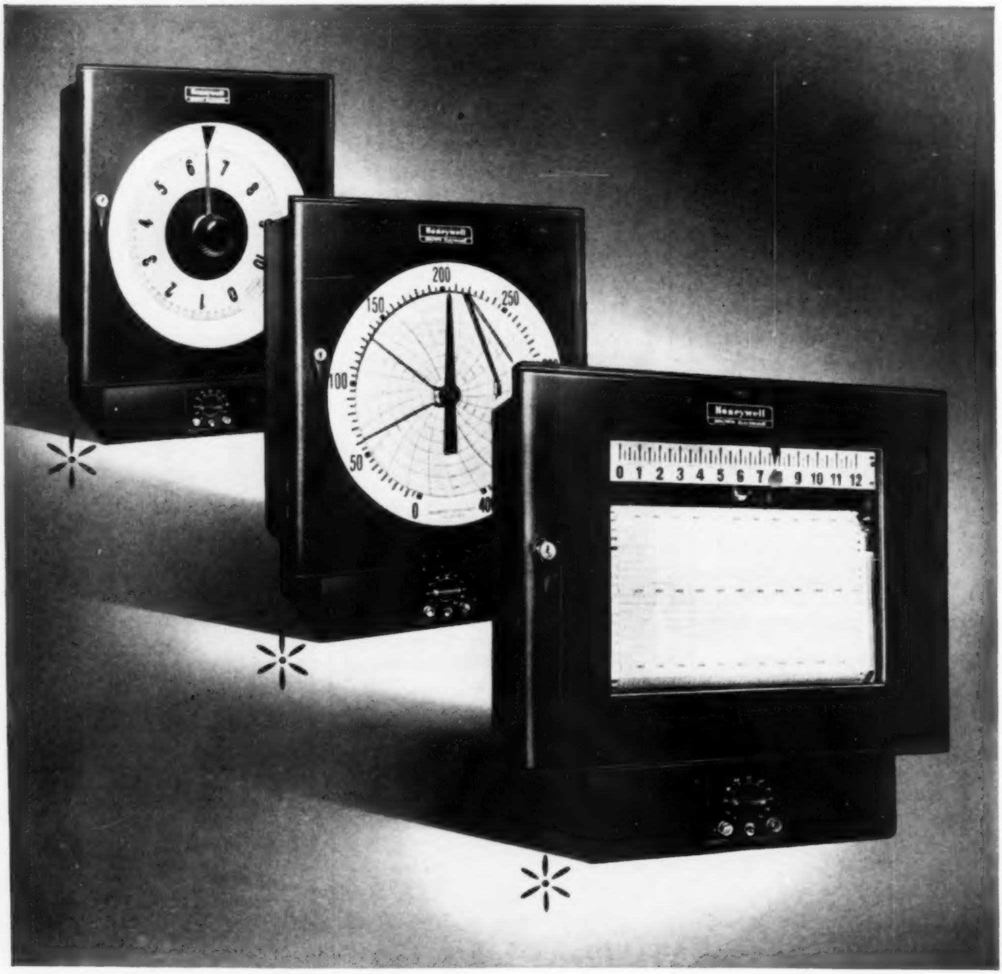

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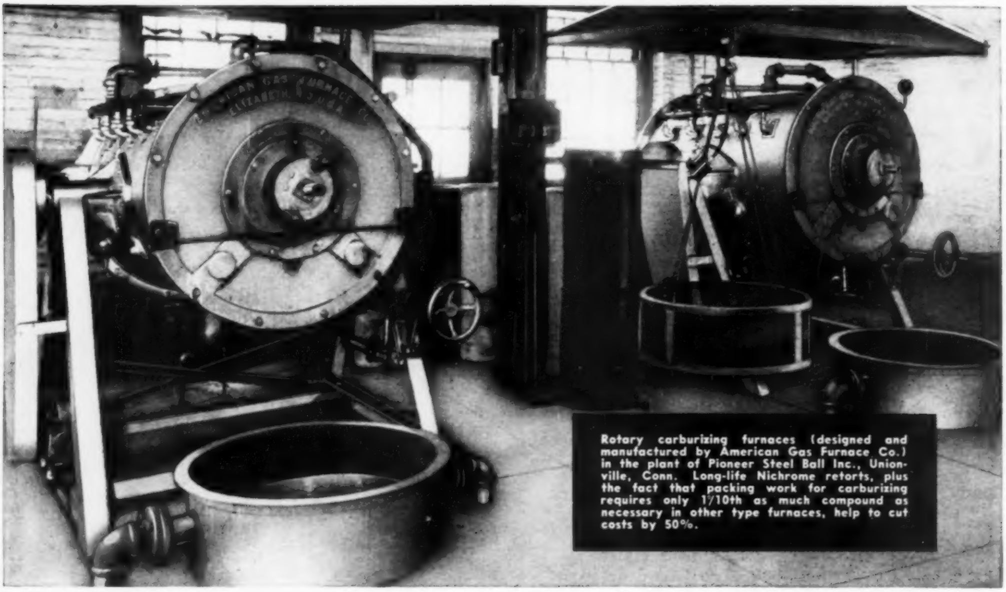

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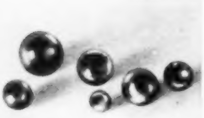

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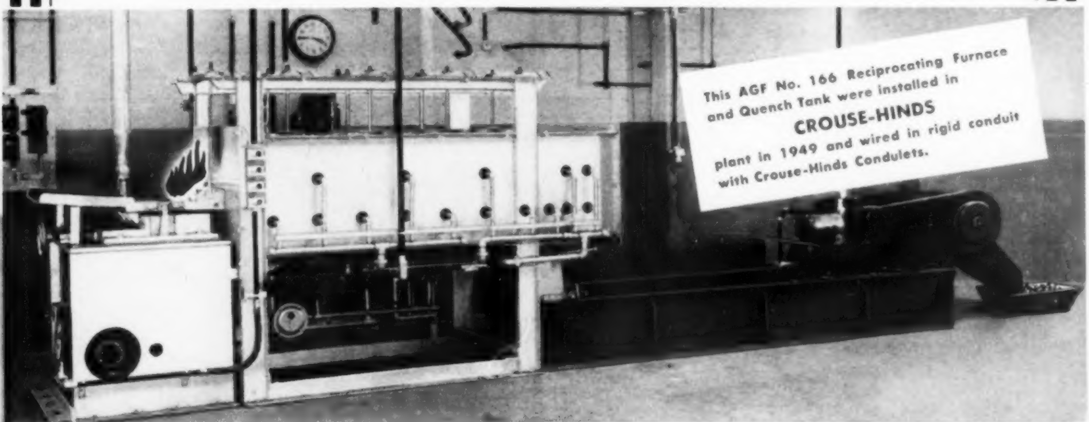

AGF is the PIONEER manufacturer of Pot Furnaces for salt bath hardening, but recognizes that AUTOMATIC RECIPROCATING FURNACES are far superior for 9 out of 10 applications.

Read this Engineer's comment —

"They call this a reciprocating controlled atmosphere furnace with quench tank and conveyor, used for carburizing and quenching clips and various other parts requiring certain hardness characteristics with high yield point, without embrittlement. The furnace is controlled within plus or minus 2½° and has been in steady use since November 1949.

"As a comparison, the operation was formerly done by heating in a salt bath in which both quantity and quality were unsatisfactory, requiring the services of an operator working under hard and undesirable conditions.

"The present operation, being fully automatic except for occasionally dumping fresh parts into the feed chute and removing a full box from the quench conveyor, gives us a product of the desired quality and quantity."

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- High production heat treating
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- Dependably uniform hardening
- No messy salt to clean
- No pots to replace
- Clean hardening results
- No dangerous sputtering or splattering
- Fully sealed muffle
- Low cost of operation
- No messy salt to replace

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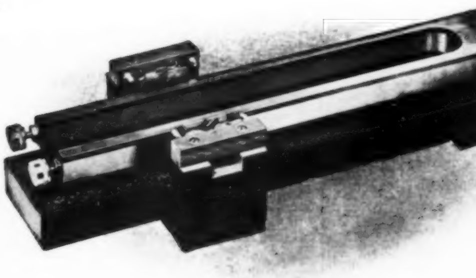
In Tune with the times



Brazing with EASY-FLO and SIL-FOS is the order of the day with thousands of fabricators of metal assemblies—first, because these low temperature silver brazing alloys make joints that have exceptional strength and lasting qualities—and secondly, because they meet today's imperative need for speed and low costs. A very interesting example is this "precision compensated tuning fork," designed for precise frequency control applications as required in geophysical and similar fields, product of the Riverbank Laboratories, Department of Engineering, Geneva, Illinois.

THE FORK PROPER is made by joining the Nickel Steel blank (1) to the Carbon Steel blank (2) with EASY-FLO (3). The two metals have opposite thermo-elastic characteristics, and, by proportioning them properly, a fork is produced that is extremely accurate and insensitive to variations in temperature.

• And now we quote in part from Riverbank's description — which says, EASY-FLO "is preferred for this application since it is imperative that a clean, strong and uniform junction be obtained. Furthermore, the alloy must not be affected by continuous displacement since a 1,000 cycle fork, for example, will vibrate 86,400,000 times in one day."

And again, the required extreme accuracy "cannot be obtained unless a perfect silver alloy joint is accomplished." Well, EASY-FLO accomplishes it . . . and proves once again that it is a top performer where quality results count.

1. Nickel Steel Blank 1/16" thick.
2. Carbon Steel Blank ½" thick.
3. EASY-FLO strip .003" thick.
Fork is approximately 10" long.

BULLETIN 20 TELLS ALL ABOUT EASY-FLO BRAZING

This 24-page bulletin is a "must" for all who design and produce metal assemblies. It explains why great strength, speed and economy are inherent in EASY-FLO brazing — and it's packed with useful information about joint design and fast production methods. Write today for a copy.

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Spheroidal-Graphite Cast Iron for Crankshafts

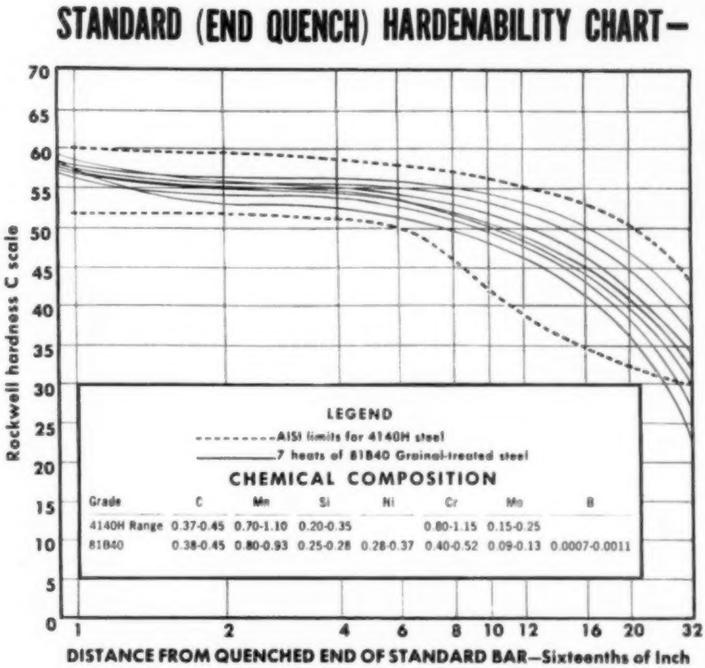
(Continued from p. 128)

steel and the normal flake-graphite types; consequently, from this point of view the new iron is perhaps not so favorable for crankshafts. On the other hand, the tests which have been carried out to date show that the wear resistance of the new iron is very good and compares favorably with the best of other types of high-duty cast iron.

Spheroidal-graphite cast iron is made by the addition of small amounts of cerium, magnesium or other metals to the iron. The magnesium process has proved the most successful and economic. This new iron has been considered of interest for cast crankshafts, and a considerable amount of experimental work attests its suitability for this application; however, it must be emphasized that much of the work on spheroidal-graphite cast iron has been carried out on the material in the annealed condition, in which a short high-temperature anneal is given to break down the pearlitic matrix to the ferritic state and to develop high ductility. The elongation of the annealed material is of the order of 10 to 25%, whereas the elongation of the material as-cast is generally not in excess of 3% unless special compositions are selected. It is anticipated that for applications such as cast crankshafts, where wear resistance is vital, attention will be focused on the pearlitic low-ductility type, as the general experience is that cast irons with microstructures including ferrite are inferior in their wear resistance.

No figures are available for the endurance limit of this grade, but some figures have been published for the annealed ferritic grade and they emphasize that, as for other cast irons, the new type has a low notch sensitivity. The actual endurance limits of the pearlitic grade would be expected to be, if anything, rather higher. In the meantime, preliminary reports on tests carried out on crankshafts are distinctly encouraging. It is true that the new iron has not the high degree of damping capacity shown by the flake graphite types — in fact, the damping capacity is nearer that of steel than of cast iron. The higher mechanical properties of the new iron offer the possibility of producing crankshafts with properties much nearer to those of steel.

(Continued on p. 148)



Grade	C	Mn	Si	Ni	Cr	Mo	B
4140H Range	0.37-0.45	0.70-1.10	0.20-0.35		0.80-1.15	0.15-0.25	
81B40	0.38-0.45	0.80-0.93	0.25-0.28	0.28-0.37	0.40-0.52	0.09-0.13	0.0007-0.0011

Consistent Hardenability obtained in Boron Steels made with GRAINAL ALLOYS

The most common test for boron steels is measurement of hardenability by the end quench or Jominy hardenability test. Today's steel substitutions are made on the basis of similar hardenability since a reasonable prediction can thus be made of the hardness and strength of a given part.

The curves above show the relationship between the hardenability of a series of seven heats of 81B40 steel and the hardenability band for 4140H steel, which it often replaces. The 81B40 heats were made in one electric furnace shop, and the remarkably consistent hardenability shown by the curves was obtained by the use of Grainal alloy as the means of adding the boron.

Consistent hardenability means consistent strength and hardness after heat treatment, which is the aim of every fabricator. The best proof that the Grainal alloys insure this objective is found in the successful use of three million tons of Grainal-treated steels.

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Spheroidal-Graphite Cast Iron for Crankshafts

(Continued from p. 146)

while having the full production economies possible with a readily cast metal.

Preliminary wear tests have been reported, and show that the resistance to wear of the spheroidal-graphite iron under laboratory conditions is good. It is reported that the wear resistance of such cast iron under lubricated conditions is excellent, in particular when free ferrite is absent. There seems no doubt that the spheroidal-graphite iron will be of great interest to engine designers, not only for crankshafts, but for other items, including rocker arms, pistons, cylinder heads, liners, and timing gears. Tests have been carried out on spheroidal-graphite cast iron with an acicular matrix, developed by suitable additions of nickel and molybdenum. There are indications that tensile strength in this type of material can easily reach 50 to 60 tons per sq.in., with the other mechanical properties proportionately increased.

D. C. WILLIAMS

High-Temperature Alloy for Rotor Blades*

A STUDY of the influence of systematic variations in composition and heat treatment on creep and rupture properties led to a wrought austenitic alloy having a composition of 0.3 C, 0.8 Mn, 0.3 Si, 19 Cr, 12 Ni, 45 Co, 2.8 V, 2.0 Mo, 1.2 Cb and 16 Fe.

The heat treatment of this alloy, known as G32, is to oil quench from 2335° F. after a 10-min. soak and then age for 46 hr. at 1380° F.

Starting with a base composition of 20 Cr – 20 Ni – 20 Co and making an arbitrary choice of variables, an investigation was made of the influence on properties of various carbide formers (W, Mo, Cb, V, and Ti) added singly and simultaneously, carbon variations, Cr, Ni, and Co variations and heat treatment of optimum compositions. The constitution of representative alloys was also studied.

(Continued on p. 150)

*Abstract of "Development of a High-Temperature Alloy for Gas Turbine Rotor Blades", by G. T. Harris and H. C. Child, Symposium on High-Temperature Steels and Alloys for Gas Turbines, British Iron and Steel Institute, February 1951, p. 67.

High-Temperature Alloy for Rotor Blades

(Continued from p. 148)

It was found that to achieve outstanding high-temperature properties two important factors must be considered and carefully controlled: *(a)* The balance between the carbon and the carbide-forming elements and *(b)* the "complexity" effect, which requires the alloy to contain at least three carbide formers in proper proportion and balance. It is theorized that the strengthening effect of the carbide-forming elements exists in such precipitation-hardened alloys as a result of empirically adjusting their compositions to slightly exceed the solubility limit at the service temperature. It is further considered that the useful aging temperature range is broadened by the precipitation of two or more phases at different temperatures. Also, the resistance to overaging can possibly be expected to increase with increasing complexity of the carbide phases formed.

An ingenious method of presenting the results as "isoproperty" contours on ternary and quaternary composition diagrams indicated that for best high-temperature properties the alloy base should be cobalt-rich (40 to 45%). About 20% chromium was necessary for scale resistance. Iron and nickel, although somewhat deleterious, were maintained around 15% for practical purposes to permit the use of ferro-alloys and facilitate machining. A combination of V-Mo-Cb additions to the base composition gave alloys with properties somewhat superior to those with W-Mo-Cb additions. The optimum strengthening composition for the base analysis was found to lie within rather small limits, around 0.3% C and a 6% total of V, Mo and Cb. While wide limits were indicated for the proportions of V, Mo, and Cb, the 2.8 V, 2.0 Mo, 1.2 Cb analysis was most attractive.

Small Ti and Al additions to alloys containing Mo-Cb improved rupture ductility without changing creep or rupture strength at 1380° F. However, such additions significantly reduced these properties at 1470° F.

The above effect of composition studies was arbitrarily made on material air cooled from 2340° F. after a 2 or 3-min. soak. Investigation of heat treatment variables indicated that water or oil quench-

(Continued on p. 154)

High-Temperature Alloy for Rotor Blades

(Continued from p. 150)

ing from this temperature gave a marked improvement in high-temperature strength properties. Solution treatment temperatures above the solidus, which produced an intergranular eutectic-like carbide phase (this did not impair the elongation at fracture) rather than globular carbides, resulted in maximum properties. Because of possible difficulties in manufacturing resulting from such a treatment, it is recommended that temperatures at or just below the solidus for 5 to 15 min. be used. Fully aging at 1380 to 1470° F. enhanced the creep strength but had no effect on rupture strength.

The nature of the precipitated phases was studied by means of electrolytic extraction and subsequent X-ray and chemical examination. The carbide-forming power of the elements Cr, Mo, W, and Cb was found to increase in that order. Age hardening appeared to be associated with the formation of a $(W,Mo,Cr,Fe)_{23}C_6$ phase. Other excess constituent phases identified in 0.5 C – 20 Cr – 20 Ni – 20 Co – Mo – W – Cb alloys were $Fe_4(Mo,W)_2C$ and Cb_4C_3. In alloys containing vanadium the vanadium carbide was in solid solution in the phase $(Cb,V)_4C_3$.

E. E. Reynolds

The Welding of High-Pressure Pipes*

Defects in a high-pressure pipe line of a power station initiated an investigation of the problem of manufacturing welded pipe lines capable of withstanding the high pressures they are subjected to, these ranging from 3 to 50% of the pressure head. The pipe line in this instance was made of boiler plate that had not been normalized; it was susceptible to brittle fracture, especially in the existing sheet thickness of 30 mm. (1.18 in.). For a safe service, the material should be free of the tendency for brittle fracture and its yield and tensile strengths should be as high as possible. A closely related factor is the behavior of unannealed circumfer-

(Continued on p. 156)

*Abstract of "Welding Problems With High-Pressure Pipe Lines", by H. Hauttmann, *Bergund Hüttenmännischen Monatshefte*, Vol. 95, December 1950, p. 314-317.

The Welding of High-Pressure Pipes

(Continued from p. 154)

ential seams during service stresses.

The Vereinigte Österreichische Eisen- und Stahlwerke Linz carried out pressure investigations with pipe units similar to those used in practice, each section being 39 in. long, 4.3 in. in diameter and having a wall thickness of 0.78 in. Two such sections were joined so that the longitudinal seam was translocated by 180°. In this testing arrangement, as in the pressure system, tangential forces only acted on the tube wall. At first, it was not possible to prevent the propagation of a crack, although according to the deposition weld-bending test (a flow-bend test employing a longitudinal weld bead and similar in scope to the Kinzel test) the steel was not susceptible to brittle failure. The rupture extended the entire length of the tube.

As a result of the experiments, the firm developed the so-called "Aldur" steel for welded structures which prevents the cracks on the circumferential seam from extending into the parent plate. This steel has the following composition: 0.16 C, 0.24 Si, 1.0 Mn, 0.018 P, 0.022 S, and 0.055% Al. Its yield and tensile strengths are 49,700 and 69,000 psi., respectively; elongation ($l = 5$ diameters) is 33%.

In one test the whole pipe unit, consisting of two pipe sections, was given a stress-relieving anneal. A crack developed under a pressure of 25,100 psi. at a weak spot in the circumferential seam after the occurrence of a permanent deformation of 12.6% in the circumference. The elongation to the right and left of the seam was 10 and 17.2%, respectively. The results of a pressure test on a unit having stress relieved components but with a nonannealed circumferential seam were satisfactory also. Again, only the circumferential seam cracked (the pressure being 25,900 psi.); permanent deformation at this spot was 9.9%, and the highest elongation in the plate amounted to 10.6%. As already mentioned, the crack was restricted to the seam.

The last investigations that have been carried out by this firm show that it is possible to manufacture steels with good weldability and low susceptibility to brittle fracture and having a yield strength of not less than 56,700 psi. and a tensile of 82,000 to 96,000 psi.

OTTO MIRT

Mechanical Descaling Method for Wire*

An important innovation in wire drawing, which has taken thirty years of experimental work to evolve, is the descaling of wire rods and the drawing of satisfactory wire without the use of liquid cleaning agent and lubricant. The process consists of cracking the scale by means of multiple bending of the wire, the deformed wire then passing through a wire-brush buffing machine which is said to remove 99% of the scale before the wire enters the drawing die. The drawing lubricant is a powdered heavy metallic soap. This process and the equipment used are covered by patents held by the Société Métallurgique de Gorcy, the machinery is made under license by Liné-Jost of Albert, Somme, France. Plants operating at Luisenthal (Saar Valley) and St. Ingbert have been successfully producing 1000 tons per month since the early part of 1950.

Three important problems had to be overcome in solving the difficulties encountered in the early stages of this development. These are *(a)* the best method of deforming the wire to properly loosen the scale, *(b)* a satisfactory brush to thoroughly remove the loosened scale, and *(c)* a dry lubricant which would permit standard reductions at ordinary drawing speeds without excessive die wear and breakage of the wire.

After trying many variations of equipment for deforming the wire, this was simply and effectively accomplished by pulling the hot rolled rod over a pulley mounted on a vertical shaft and then passing it over a pulley mounted on a horizontal shaft. Thus the wire is bent 90° in the horizontal plane and then 90° in the vertical plane. It then passes through a nest of buffing brushes which revolve on vertical shafts perpendicular to the direction of wire travel. It is claimed that this operation removes 99% of the scale and eliminates the pickling, rinsing, sulling, lime coating and baking which are conventional practice for the "dry" wire drawing process.

A large number of brushes were investigated but the only satisfactory type was a brush having stiff, steel wire bristles. The important details regarding the brushes and

(Continued on p. 160)

*Abstract of "The Method and Results Obtained With a Machine for Descaling Wire", by Von Walter Zwierz, *Stahl und Eisen*, Oct. 25, 1951, p. 1133-1137.

Lepel *presents*

A *Low Cost* PORTABLE HIGH FREQUENCY *Induction* HEATING UNIT

BRAZING
Permits widest choice of silver or copper brazing alloys from lowest to highest melting points. Ideal for brazing carbide tips.

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Heat localized exactly where wanted at desired temperature. Ideal for gears, cams, bearing surfaces, cutting tools and other areas that are subject to wear.

SOLDERING
Speedily and neatly performs intricate soldering applications with or without the use of pre-formed rings.

ANNEALING
Ideal for annealing, stress-relieving, normalizing or preheating selected areas.

MELTING
Readily melts quantities of ferrous and nonferrous metals in either graphite or ceramic crucibles.

- **SMALL AND COMPACT**
  Conveniently operated on bench or table—no mounting necessary.
- **ECONOMICAL OPERATION**
  No special power installation required. Operates on 110 volts, 60 or 50 cycle line at unity power factor.
- **FULLY GUARANTEED**
  Guaranteed for continuous duty cycle and stated performance.

This versatile unit is priced so low that every shop may now take advantage of modern induction heating techniques to improve quality and to increase production. Its simplicity of operation eliminates the need for skilled personnel.

The Lepel Model 2 KW will meet the requirements of machine shops, toolrooms, research laboratories and educational institutions. It is especially suitable for hardening, brazing and soldering small parts of either ferrous or non-ferrous metals.

Complete unit with line connection and load coil.

$870.
f.o.b. factory

WILL HEAT TO 1500° F.

⅛" steel rod 1" length in approx.	1 second
¼" " " " " " "	3 seconds
½" " " " " " "	15 seconds
1" " " " " " "	60 seconds

Will melt 4 ounces of brass or steel in 4 minutes.
Equally well suited for heating of non-ferrous metals.

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Write for Lepel Catalog MP-4

Mechanical Descaling Method for Wire

(Continued from p. 158)

lubricants are purposely omitted in the article.

At first, the drawing dies lasted only a few hours because of the excessive wear, but this has been overcome in recent practice and dies can now be used for three or four weeks. Part of this difficulty resulted from ineffective scale removal because of poor brushes and part to uneven distribution of the lubricant, the dies wearing out very rapidly on one side. The wire must be dry and should not be processed for at least 24 hr. after hot rolling. The brushes now used are good for 150 to 200 hr. of service; the weight of scale removed approximates 22 lb. per ton of steel. Total power requirement is stated to be about 4 kw-hr. per ton over that required for pickled wire; drawing speed is 3 ft. per sec., the same as for pickled wire. Present die life is 10% less than that obtained on pickled wire. It is assumed that this refers to tungsten carbide dies. The finished product is equal in all respects to wire made from pickled rods.

Total reduction on the mechanically cleaned wire is less than for a chemically cleaned wire. It is only possible to draw from 5 mm. (0.197 in.) to 0.9 mm. (0.035 in.) before it is necessary to anneal the coil; the pickled wire may be drawn from 5 mm. (0.197 in.) to 0.6 mm. (0.0236 in.) before annealing.

All interpass or process annealing in these plants is done in bright annealing furnaces when making smaller wire sizes, so neither mechanical nor chemical cleaning is necessary. The mechanically cleaned wire is entirely satisfactory for galvanizing. This process is at present limited to wire having less than 0.30% carbon. The total cost of this process is given as:

Item	Marks per Ton
Dies + 10%	0.09
Brushes	0.048
Labor	0.792
Maintenance	0.036
Transportation	0.228
Power	1.245
Lubricant	0.660
TOTAL	3.099
Scale Credit	0.600
NET COST	2.499
Total Pickling Wire Cost	9.000
SAVING	6.501

Based on the exchange rate of four Deutsch marks per dollar, this is a saving of $1.635 per metric ton.

E. C. WRIGHT

Influence of Surface Condition on Quenching Rates*

PRIOR RESEARCH at the Max Planck Institute used silver spheres quenched in various media. Originally the temperature at the center was observed; later a technique was developed to determine the rate of temperature change directly — that is, without having first to draw the time-temperature curve. By this means various quenching media were compared.

Since the surface character has considerable bearing on the cooling rates, the present work was extended to include iron spheres with cleaned, scaled and salt-covered surfaces. Next, by quenching samples of various steels, the validity of the previous findings for silver and iron spheres was established. Temperatures were measured 0.02 in. below the surface. The experiments used a number of quenchants which can be grouped into three classes:

The first class comprises coolants which extract heat from the steel mainly by conduction and convection (exemplified by molten salts), and results in high cooling rates at high temperatures, the rates decrease as temperatures decrease.

The second class is composed of coolants which extract heat mainly by evaporation. Water and oils belong to this group. Cooling rates in these start at relatively low values and increase at lower temperatures.

The third class cools by combined action and is exemplified by water solutions of salt or caustic.

The influence of scale is shown in Fig. 1 and 2 (p. 164). The salt bath was a mixture of NaCl and KNO_3 melting at 285° F.; the quenching oil was a commercial product of 0.910 specific gravity, Engler viscosity of 7.5 at 20° C. and 2.2 at 50° C., and had a flash point of 330° F.

In coolants of the first class which cool by conduction (molten salt, Fig. 1), scale on the iron does not change the nature of the cooling-rate curve, but merely slows the cooling according to the thickness of the scale.

In coolants of the second class which cool by evaporation (water

(Continued on p. 164)

*Abstract of "The Influence of Surface Conditions of Metals on the Cooling Rates in Liquid Quenchants", by Walter Peter, *Archiv für das Eisenhüttenwesen*, Vol. 21, November-December 1950, p. 395.

RAMMED CHROME HEARTH *lasted 2 weeks*

Pusher type, oil fired furnace. Temperature at entrance end 1000 F; 2400 F at discharge end.

"CARBOFRAX" SKIDS STILL GOOD *after 2 years*

For 16 hours (sometimes 24 hours) a day, five days a week, forging billets are pushed through this furnace. When it was equipped with a rammed chrome ore hearth, about two weeks of this punishment was all the furnace could take. The hearth would cut out. The furnace would have to come down for repairs.

Then, in December 1949, CARBOFRAX silicon carbide skid rails were installed. The furnace was started up, and exactly one year later, 16,554 tons of billets had been pushed over these skids. And they still looked as good as new.

Four months later, the furnace was down for some rearrangement of the front end. The close-up shows one of the skid rail brick as it appeared at that time — worn down only 1/16"!

Today, these skids are still in service, still in good condition.

Think what this means in terms of down time, labor, and materials . . . savings you might make, too. Write today for further information. Our address: Dept. C-32, Refractories Div., The Carborundum Co., Perth Amboy, N. J.

Use Super Refractories by

CARBORUNDUM

Trade Mark

"Carborundum" and "Carbofrax" are registered trademarks which indicate manufacture by The Carborundum Company

Influence of Surface Condition

(Continued from p. 162)

or oils as shown in Fig. 2), the scale not only causes lower maximum cooling rates as compared with clean surfaces, but may change the character of the curve.

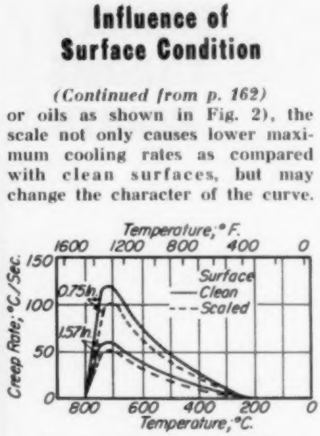


Fig. 1 — Influence of 0.04-In. Scale on Cooling Rates of Iron Spheres in Salt at 390° F.

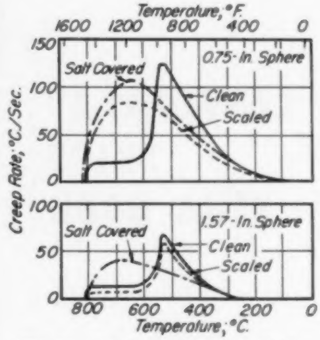


Fig. 2 — Influence of 0.04-In. Scale or a Salt Layer on Cooling Rates of Iron Spheres in Oil at 105° F.

The cooling-rate curve is of the same shape for a 1.57-in. sphere whether cleaned or scaled (the presence of scale apparently prevents formation of a vapor layer), whereas it has a different maximum for the smaller 0.75-in. sphere. The authors conclude that if the surface is covered with scale of what might be called "sufficient thickness", the cooling-rate curves are quite different from those for clean surfaces. At high temperatures (over 1100° F.) the rates of the scaled surface are then much higher than those of the clean surface, but lower at temperatures below 900° F.

In another series of experiments on oil-quenched 1.57-in. spheres, the scale was varied. Scale 0.04 in. thick gave cooling-rate curves like the lower one for scaled sphere in Fig. 2. Scale about 0.10 in. thick gave a curve of about the same

(Continued on p. 166)

Influence of Surface Condition

(Continued from p. 164)

shape as the "salt covered" curve at the bottom of Fig. 2, but it was very irregular and jagged at temperatures above 1300° F. This was apparently caused by repeated formation and subsequent collapse of vapor layers. A thickness of 0.04 in. of scale was apparently not sufficient to prevent vapor formation; "sufficiency" of a scale layer seems to depend on the thermal conductivity of the metal and the scale, and on the heat content of the sample: the larger the sphere (and therefore the ratio of heat content to the surface area) or the higher its thermal conductivity, the thicker the scale layer must be in order to be "sufficient" to prevent the formation of vapor when quenched in oil or water.

It is impossible to establish quantitatively the critical value of the ratio, heat content to surface area, because there are too many factors which influence the scale thickness and its conductivity. Moreover, these factors vary in the shop, according to the condition of the surface prior to heating, time and temperature of heating, and especially the furnace atmosphere. The conductivity of the layer is influenced by its porosity, the chemical composition of the steel, and by an air gap which may form between metal and scale. Furthermore, influence of the quenchants may be another factor.

Sometimes the charge is heated in a salt bath and it arrives in the quenching bath covered with a salt layer. Some experiments were carried out to show the influence of such a layer on the cooling rates. The results for the large and small iron spheres were the same, so reference to the 1.57-in. iron spheres will suffice. When hot specimens covered by a salt layer are quenched in molten salt or in 15% salt solution, the cooling rate versus temperature curves are slightly below those for clean specimens. These two liquids belong to the first and third class of quenchants, respectively.

The salt layer has a very pronounced influence, however, when quenching in the second class of coolants — water and oils, as shown in Fig. 3 for distilled water at 140° F. and oil at 105° F. Formation of a vapor layer is completely suppressed in oil; hence, intensive

(Continued on p. 168)

Influence of Surface Condition

(Continued from p. 166)

cooling spreads over a range including high temperatures. When quenching in distilled water, however (Fig. 3, top), a coherent vapor

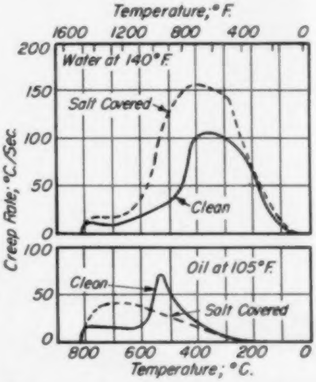


Fig. 3 — Influence of Salt Layer on Cooling Rates of 1.57-In. Iron Spheres Quenched in Distilled Water or in Oil

layer is formed which is not as stable as it is on a hot clean surface and it collapses at a temperature approximately 200° F. higher. Note that during the following boiling phase the cooling rates are approximately 50% higher than with a clean surface.

QUENCHING OF SMALL PIECES

The above data from iron spheres were then correlated with the quenching of small pieces of commercial steels as follows:

STEEL	QUENCHING TEMPERATURE
C1095 (0.25 Si)	1475° F.
C1060	1600
C1080	1510

Sizes of the samples were ½ x ½ x 1½ in., ¾ in. diameter x 1½ in., and 1 in. diameter x 1½ in., respectively.

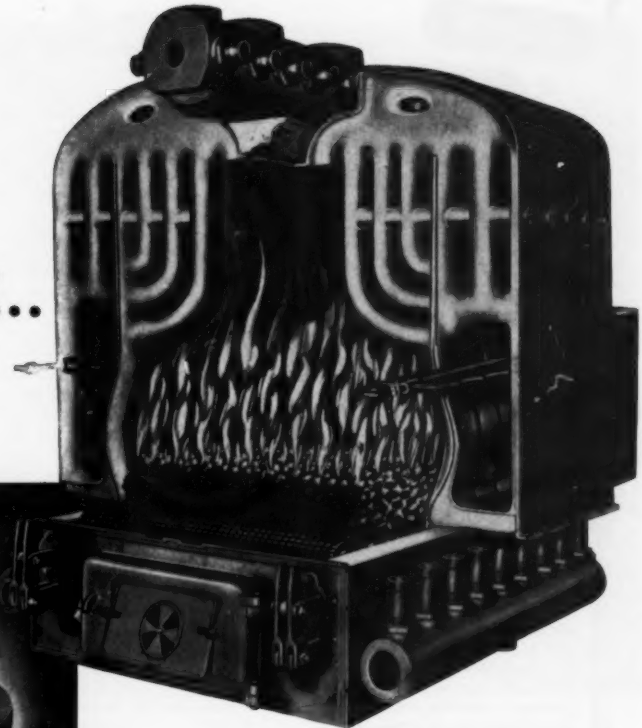
Critical points of these steels were about equal (around 1340° F.). Beginning of transformation to fine pearlite on continuous cooling was more rapid in C1095, somewhat slower in C1060, and slowest in C1080. "Nose" of the transformation curve occurred as follows:

STEEL	COOLING RATE	TEMPERATURE	TIME
C1095	660° F./sec.	940° F.	1.2 sec.
C1060	390	930	2.4
C1080	300	880	3.1

Martensite points were 340, 480, and 390° F., respectively.

(Continued on p. 170)

"ideal for boilers"...



...or refrigerator parts!

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"GRAY IRON IS IDEAL FOR BOILER CONSTRUCTION", says the manufacturer of this boiler, "because it resists to the greatest possible extent the numerous corrosive factors that attack boilers both internally and externally. Furthermore, many boilers receive indifferent or poor care. Consequently, a very durable material is necessary for their construction."

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Influence of Surface Condition

(Continued from p. 168)

Dimensions of the samples were so selected that high surface hardness was obtained when quenching clean specimens, so the author used hardness values to express the change of cooling conditions caused by variation of surface conditions. Inasmuch as the critical cooling rates of the steels decreased in the sequence A, B, C, dimensions of the samples were increased in the same sequence.

On quenching in a 15% salt solution the three surface conditions (clean, scaled, and covered by a salt layer) resulted in no appreciable differences in hardness. The different surfaces have, however, strong influence if quenched in distilled water or oil. Hardness of samples quenched in oil are:

Steel	Hardness
Bare Sample	
C1095	C-41 to 42
C1060	C-52 to 61
C1080	C-55 to 59
Scaled Sample	
C1095	C-43 to 58
C1060	C-36 to 51
C1080	C-53 to 59*
Salt Covered Sample	
C1095	C-43 to 60
C1060	C-49 to 58
C1080	C-44 to 52

*C1080 with forging scale quenched to C-32 to 38.

All three steels have their maximum transformation rates in the temperature range at which the oil has its highest cooling effect. Nevertheless, hardness of steel A, with clean surface, is very low; steels B and C are at least partially hardened. This difference in hardenability can be explained by the shorter times required for pearlite to form in steel A (as compared with B and C) at temperatures above 1000° F. where the cooling effect of the oil, thanks to the vapor layer, is very small. Microstructure of steel A (fine lamellar pearlite) is also indicative. Pearlite transformation is delayed in steels B and C, and even then is not complete; this is verified from the higher hardness, and from the presence of more than 50% martensite at the surface.

Compared with a clean surface, scale may increase hardness (steel A), decrease it (steel B), or leave it unchanged (steel C). Steels A and B harden more readily and steel C less readily when quenched from a salt bath and having a layer of salt

(Continued on p. 172)

Wisconsin Sulfite-Treated Steel

Sulfite-Treated Steel, a highly machinable steel, is produced by a Wisconsin-developed process.

This steel undergoes a "washing" action in the ladle, to add sulphides, uniformly dispersed throughout the metal—aiding the machinability of this steel. At the same time, abrasive elements are removed.

This Sulfite-Process produces a steel with more uniform physical properties than ordinary resulphurized steel. That means fewer rejections and a better finished product. Most important of all, Wisconsin Sulfite-Treated Steel is ***far more machinable*** than ordinary steel with a ***minimum effect on physical properties.***

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180 North Michigan Avenue, Chicago 1, Illinois

WISCONSIN STEEL

Influence of Surface Condition

(Continued from p. 170)
rather than of scale. The upper part of Fig. 2 may explain this for A and B. The cooling rate over the entire cooling range for the steel with salt layer lies above the curve for the scaled steel.

Hardness tests thus confirm the conclusions drawn from preliminary tests with iron spheres. In addition they show that the change of cooling rates, caused by different surface conditions, may increase or decrease the surface hardness of the steel.

Tests with iron spheres as well as quenching experiments show that when the quenchant cools by conduction and convection only, the nature of the surface does not influence the rate of heat extraction and therewith of hardening effect. If the cooling effect of a quenchant is caused mainly by evaporation, a scale or salt layer may suppress vapor formation, and this throws doubt on conclusions based on cooling rates formerly obtained on the silver spheres.

VICTOR PASCHKIS

"Whiskers" on Metal Surfaces*

IN TRACING trouble which first was reported about five years ago in connection with failures in channel filters used in carrier telephone systems, researchers found it to be caused by the filamentary growth of extremely small and fragile "whiskers" on the leaves of electroplated variable air condensers. While only about 2 microns in diameter, some ranged up to ⅜ in. long, mostly perpendicular to the metal surface and sufficiently conductive to cause a short circuit.

The growths also appeared on cadmium-plated steel condenser leaves of military communications equipment during the early part of the war, but little investigative work has appeared on them. This led to an intensive research study by the Bell Telephone Laboratories
(Continued on p. 174)

*Abstract of "Filamentary Growths on Metal Surfaces — Whiskers", by K. G. Compton, A. Mendizza and S. M. Arnold, Bell Telephone Laboratories, Murray Hill, N. J.; first presented before National Association of Corrosion Engineers in New York and later issued as Monograph 1885 in Technical Publications of the Bell Telephone System.

"Whiskers" on Metal Surfaces

(Continued from p. 172)

in which over 1000 test specimens of different metals, solid and plated, and exposed under a variety of environmental conditions, were studied. This work has not yet been completed, but interesting preliminary data have been assembled.

The phenomenon has been observed primarily on zinc, cadmium and tin coatings. The whiskers of zinc and cadmium were found to be single crystals with a close packed hexagonal structure, oriented with an ortho-hexagonal axis parallel to the long axis of the fiber. Tin whiskers appeared to be tetragonal and to be twinned.

An environment of neither high humidity nor one contaminated by organic material is necessary, because the whiskers have developed under conditions normally considered dry and free of contaminant. While at first suspected, electroplating in itself is not the cause of the growths, since they appeared on specimens coated by other methods and on solid metal.

For a given metal, whiskers generally developed first and to a greater extent on thinner coatings, this being noticed with regard to hot dipped coatings as well as plated coatings and wedge-shaped electrodeposits. Residues of electrolytes used to prepare specimens for plating were ruled out as causes, since the whiskers appeared on solid metal and also on metal-coated paper and mica where no cleaning was involved.

Transformation of the individual metal to a more stable form does not seem a likely explanation, particularly in the case of tin where neither heat treatment nor working greatly affected the whisker growth.

In answer to the question as to why such growths have not been encountered in the past and why there is such a limited amount of information available on them, it is suggested that the fragility of the filaments may be the explanation. Slight mechanical shock, air currents or a moderate electrical potential remove the microscopic fuzz.

Time required to grow the whiskers was established to vary widely, depending upon enrivonmental conditions and ranging from a few weeks to two years.

A. H. Allen


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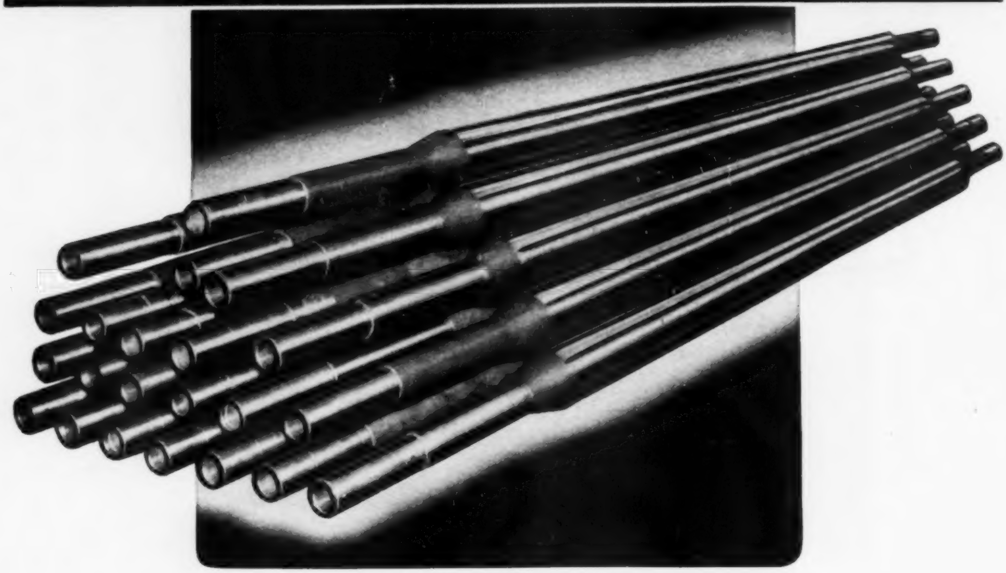

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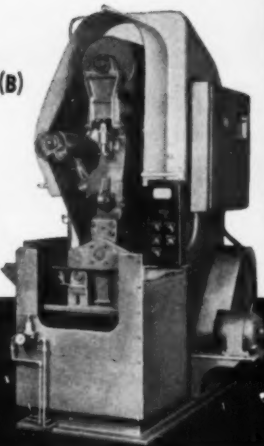
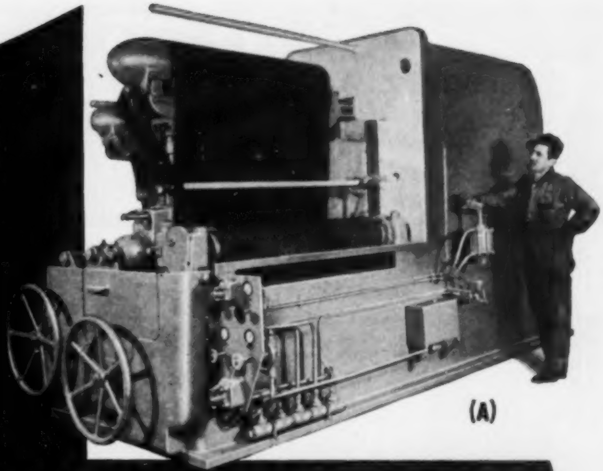
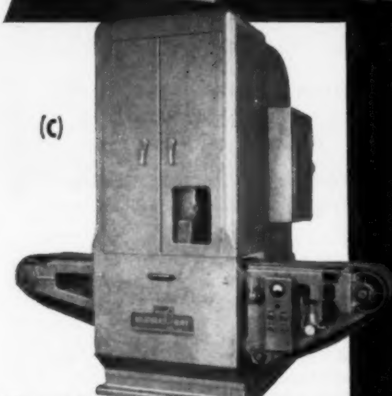
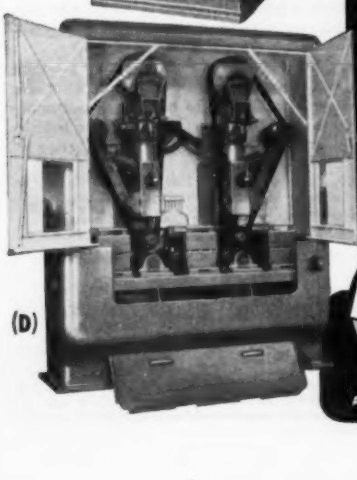




(A)

(C)





(D)

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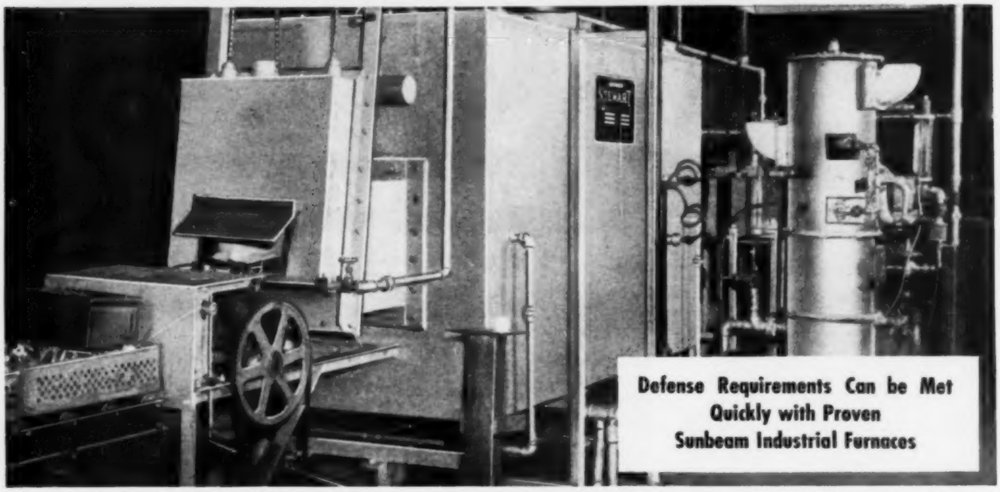
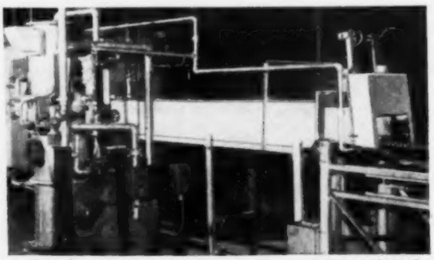


Charge and side view of Sunbeam Electric Copper Brazing furnace for copper brazing control arms. This brazed assembly, consisting of a number of machined and stamped parts, is used as a single unit, both in its heat treatment and further handling.



A 1′ x 12′ water jacketed cooling chamber cools the work in the protective atmosphere to a point below the oxidizing temperature. At left is a Sunbeam atmosphere generator which provides a bright finish to the work while eliminating decarburization.

To provide a union that would be of sufficient strength while allowing thorough visual inspection with ease of application—and still be adaptable for subsequent heat treatment—Warner Gear copper braze various control arms used on their newly designed torque converter. Pieces vary in sizes and shapes from offset control arms weighing about ½ lb. and 3½″ across to small 1½″ x 1½″ ratchets and cams weighing less than 3 oz.

This Sunbeam unit has a useable heating space 5′ long by 1′ wide with a 12″ wide by 1½′ charge vestibule. A water jacketed cooling chamber (1′ x 12′) cools the work in a protective atmosphere.

With slight modifications, this Sunbeam furnace can be used for both annealing and copper brazing high alloy and stainless steels. Availability of this equipment as a continuous production unit varies from 50 lbs./hr. up to 1000 lbs./hr. Flexibility of this furnace enables designers to utilize the simplicity in design and manufacture of brazed assemblies.

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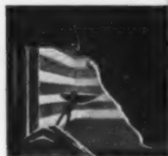

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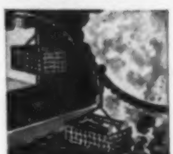

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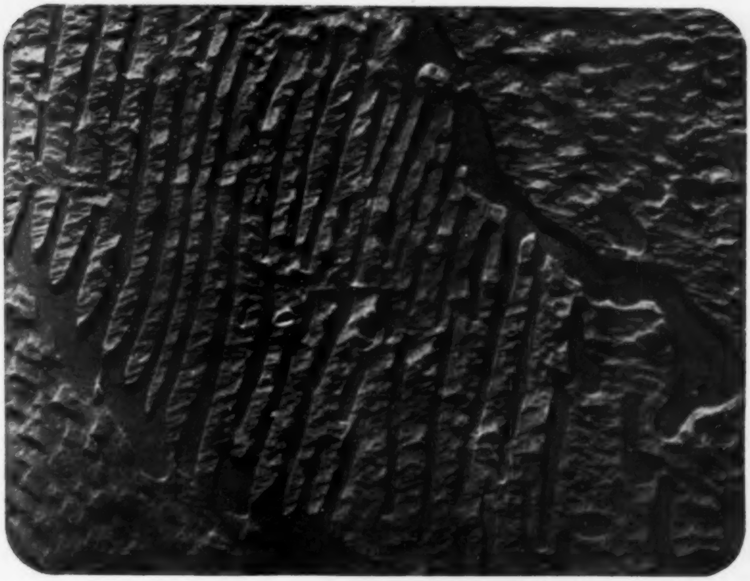

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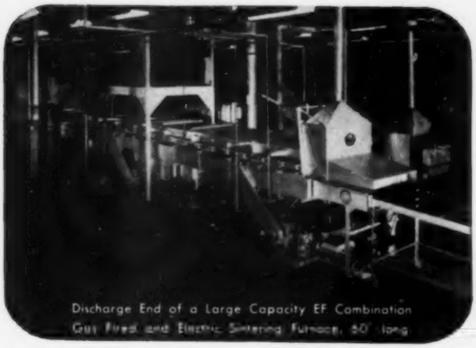

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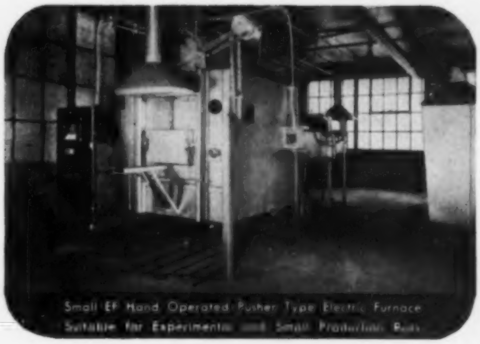

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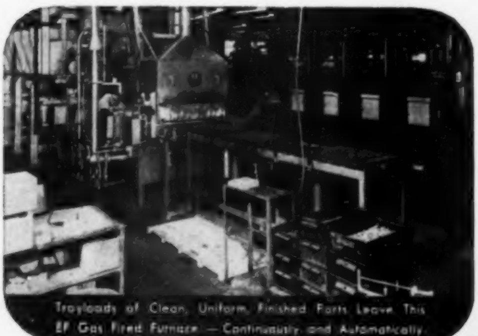

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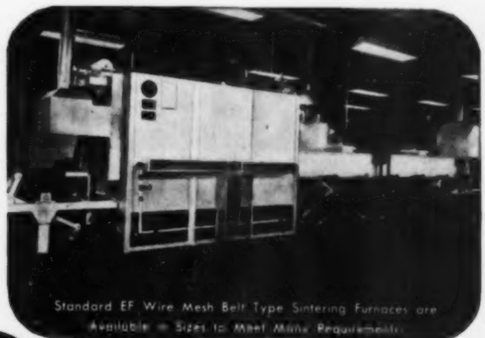

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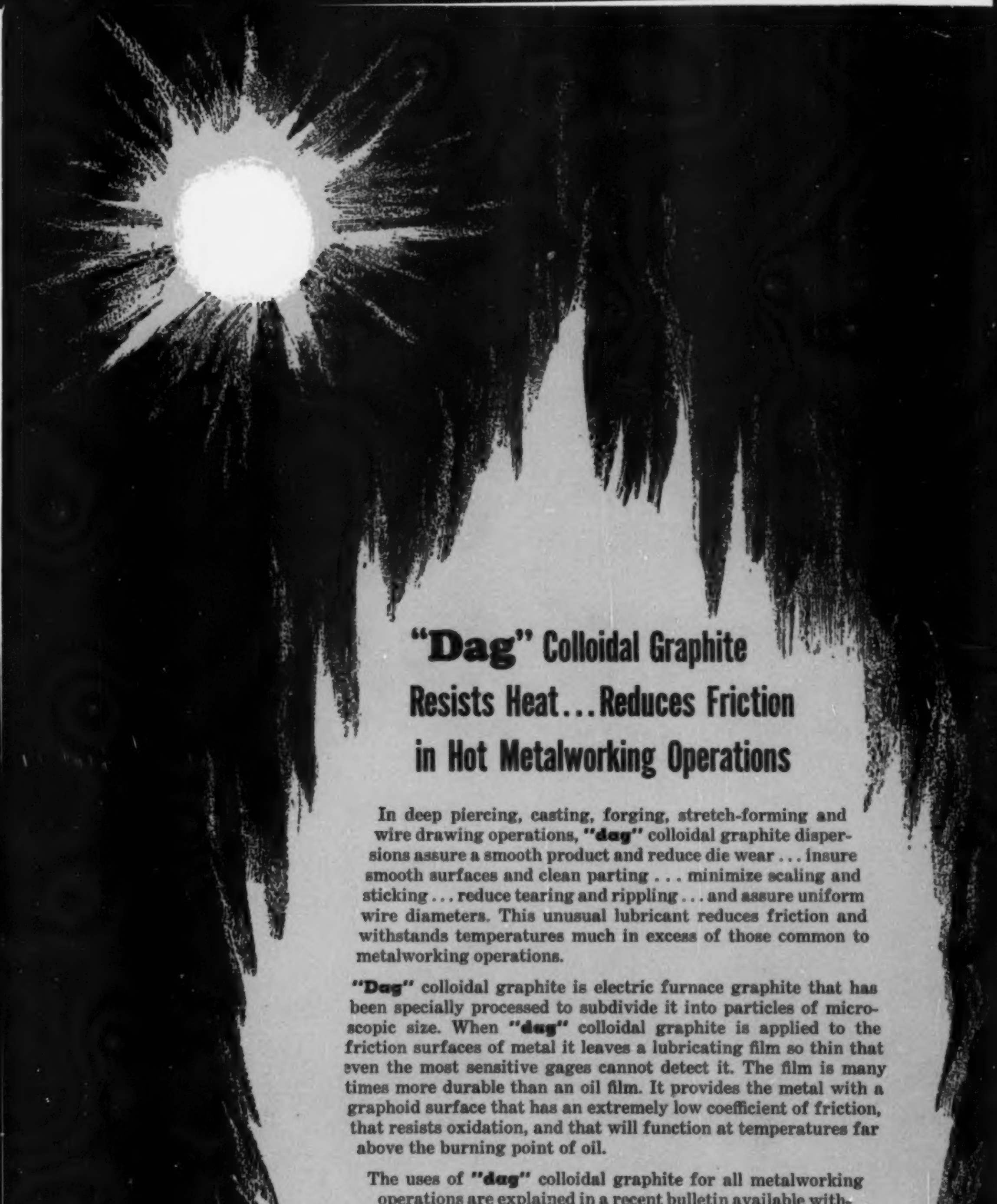

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